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**EUROPEAN PATENT APPLICATION**

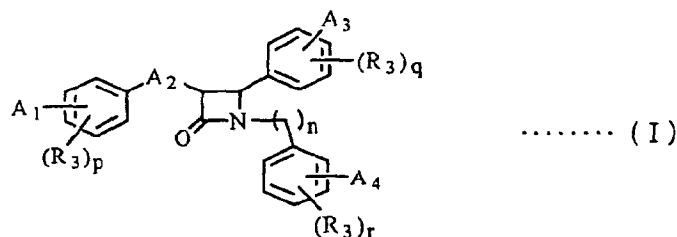
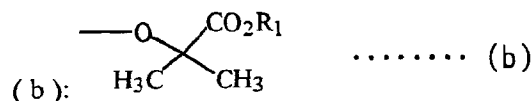
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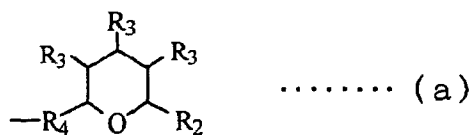
(30) Priority: **23.02.2001 JP 2001048202**  
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**Hanishina-gun, Nagano 389-0601 (JP)**(54) **BETA-LACTAM COMPOUNDS, PROCESS FOR REPRODUCING THE SAME AND SERUM  
CHOLESTEROL-LOWERING AGENTS CONTAINING THE SAME**

(57) The compounds have the following general formula (I):

[wherein: A<sub>1</sub>, A<sub>3</sub> and A<sub>4</sub> are hydrogen atom, halogen atom, alkyl group having one to five carbon atoms, alkoxy group having one to five carbon atoms, -COOR<sub>1</sub>, a following formula(wherein: R<sub>1</sub> is hydrogen atom or alkyl group having one to five carbon atoms) or a following formula

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(a):



[wherein:  $R_2$  is  $-\text{CH}_2\text{OH}$  group,  $-\text{CH}_2\text{OC}(\text{O})-\text{R}_1$  group or  $-\text{CO}_2-\text{R}_1$  group;  $R_3$  is  $-\text{OH}$  group or  $-\text{OC}(\text{O})-\text{R}_1$  group;  $R_4$  is  $-(\text{CH}_2)_k\text{R}_5(\text{CH}_2)_1-$  ( $k$  and  $1$  are 0 or 1 more integer;  $k+1$  is 10 or fewer integer);  $R_5$  means bond (single bond  $-$ ),  $-\text{CH}=\text{CH}-$ ,  $-\text{OCH}_2-$ , carbonyl group or  $-\text{CH}(\text{OH})-$ .]. One of  $A_1$ ,  $A_3$  and  $A_4$  in formula (I) is must be the group in above mentioned formula (a).  $A_2$  is alkyl chain having one to five carbon atoms, alkoxy chain having one to five carbon atoms, alkenyl chain having one to five carbon atoms, hydroxyalkyl chain having one to five carbon atoms or carbonylalkyl chain having one to five carbon atoms.  $n$ ,  $p$ ,  $q$  or  $r$  are 0, 1 or 2.] or their pharmaceutical acceptable salts.

**Description****[Field of the invention]**

**[0001]** This invention related to novel  $\beta$ -lactam compounds, a manufacturing method of these compounds and a serum hypocholesterolemic agent contained these compounds.

**[Background of the invention]**

**[0002]** Hypercholesterolemia is a risk factor for atherosclerotic heart disease. Atherosclerotic heart disease represents the major cause for death and cardiovascular morbidity in the world (Lipid Research Clinics Program. J.Am.Med. Assoc., 1984, 251, 351 or 365). Recently, HMG-CoA reductase inhibitors have been used as the hypocholesterolemic agents in clinical. HMG-CoA reductase inhibitors are shown to have a potent serum hypocholesterolemic activity, however, they are also reported to have unfavorable side effects (Mevacor in Physician's Desk Reference, 49th ED, Medical Economics Data Production Company, 1995, 1584). Therefore, the potent and safety serum hypocholesterolemic agents are desired.

**[0003]** It has been reported that naturally occurring glycosides have serum hypocholesterolemic activity (M. A. Farboodniai Jahromi et al., J.Nat.Prod., 1993, 56, 989., K. R. Price, The Chemistry and Biological Significance of Saponins in Foods and Feeding Stuffs. CRC Critical Reviews in Food Science and Nutrition, CRC Press, 1987, 26, 27). It is considered that these glycosides reduce serum cholesterol levels due to the inhibition of cholesterol absorption in small intestine (P. A. McCarthy et al., J.Med.Chem., 1996, 39, 1935). Additionally, some  $\beta$ -lactam compounds are reported its hypocholesterolemic activity (S. B. Rosenblum et al., J.Med.Chem., 1998, 41, 973, B. Ram et al., Indian J.Chem., 1990, 29B, 1134. USP 489, 3597).

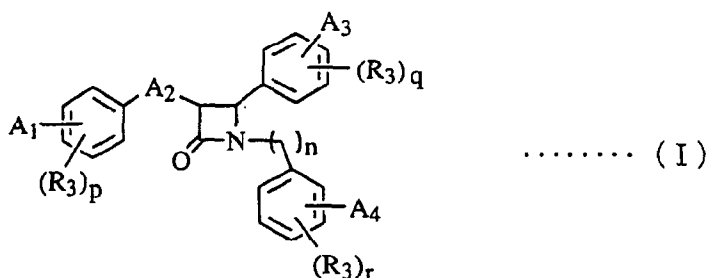
**[0004]** The  $\beta$ -Lactam compounds have a weak inhibitory activity on cholesterol absorption themselves, and further the glucuronide of the  $\beta$ -lactam compounds are more potent than the parent  $\beta$ -lactams. In the absorption process, the  $\beta$ -lactam compounds are rapid glucuronidated in small intestine after oral administration, and the resulting glucuronide derivatives are secreted through bile-duct to small intestine. These  $\beta$ -lactam-O-glucuronic acid conjugated derivatives are located to mucosal layer in small intestine, a site of action, and inhibit cholesterol absorption (M.van Heek et al., Brit.J.Pharmacol.,2000,129,1748., J.Pharmacol.Exp.Ther.,1997,283,157). Because of the above mentioned  $\beta$ -lactam compounds show serum hypocholesterolemic activity in small intestine by  $\beta$ -lactam-O-glucuronate conjugated derivatives, the hypocholesterolemic activities of these compounds incorporating glucose or glucuronic acid derivatives were synthesized (W. D. Vaccaro et al., Bioorg.Med.Chem.Lett., 1998, 8, 313). However, it is considered that the O-glycoside bonds in these compounds are readily hydrolyzed with glycosidase existed in small intestine after oral administration, and it is supposed the hypocholesterolemic activities of these compounds in small intestine will be reduced. Thinking about the active site of these  $\beta$ -lactams is mucosal layer in small intestine, the better cholesterol absorption inhibitors are required to act just only in small intestine with high efficacy and long duration. It is expected that ideal cholesterol absorption inhibitors are not to be absorbed in small intestine and eliminated without absorption in small intestine so that side effects will be reduced after the absorption in small intestine.

**[0005]** The principal object of the present invention is the provision of novel hypocholesterolemic agents having  $\beta$ -lactam moiety and C- glycoside in the molecules, which is stable to metabolism by glycosidase and hydrolysis with acids or bases. Namely, the object of the present invention is the provision of hybrid molecules with  $\beta$ -lactam and C-glycoside as hypocholesterolemic agents.

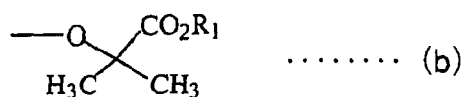
**[Detailed description of the invention]**

**[0006]** We thought that the  $\beta$ -lactam and C-glycosides hybride compounds are metabolically stable against glycosidase and hydrolysis with acids or bases (R.J.Linhaldet al.,Tetrahedron,54,9913-9959,1998). Firstly, the  $\beta$ -lactam - C-glycoside compounds are expected to be stable against glycosidase existed in small intestine and these hybrids were possible to locate at mucosal layer in small intestine in long time. Secondly, we thought that these compounds were little absorbed at mucosal layer in small intestine so that the side effects will be reduced. In the effort for the discovery of novel  $\beta$ -lactam compounds having serum hypocholesterolemic activity, we found that the compounds of the general formula (I) are the excellent hypocholesterolemic agents

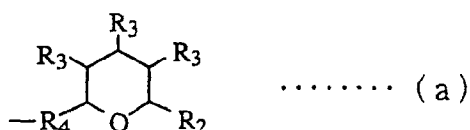
**[0007]** Namely, the compounds of the present invention have the following general formula (I):



[wherein: A<sub>1</sub>, A<sub>3</sub> and A<sub>4</sub> are hydrogen atom, halogen atom, alkyl group having one to five carbon atoms, alkoxy group having one to five carbon atoms, -COOR<sub>1</sub>, a following formula (b):



(wherein: R<sub>1</sub> is a hydrogen atom or an alkyl group having one to five carbon atoms) or a following formula (a):



30 (wherein: R<sub>2</sub> is -CH<sub>2</sub>OH group, -CH<sub>2</sub>OC(O)-R<sub>1</sub> group or -CO<sub>2</sub>-R<sub>1</sub> group; R<sub>3</sub> is -OH group or -OC(O)-R<sub>1</sub> group; R<sub>4</sub> is -(CH<sub>2</sub>)<sub>k</sub>R<sub>5</sub>(CH<sub>2</sub>)<sub>l</sub>- (k and l are 0 or 1 more integer; k+1 is 10 or fewer integer); R<sub>5</sub> means bond (single bond (-), -CH=CH-, -OCH<sub>2</sub>-, carbonyl group or -CH(OH)-).

35 **[0008]** One of A<sub>1</sub>, A<sub>3</sub> and A<sub>4</sub> in formula (I) is must be the group in above mentioned formula (a). A<sub>2</sub> is alkyl chain having one to five carbon atoms, alkoxy chain having one to five carbon atoms, alkenyl chain having one to five carbon atoms, hydroxyalkyl chain having one to five carbon atoms or carbonylalkyl chain having one to five carbon atoms. n, p, q or r are 0, 1 or 2.] or their pharmaceutical acceptable salts.

40 **[0009]** Furthermore, this invention related to a manufacturing method of the compounds of general formula (I) and pharmaceutically acceptable salts thereof. This invention also related to a serum hypocholesterolemic agent contained the compounds of general formula (I) and their pharmaceutically acceptable salts. Additionally, this invention related to a serum hypocholesterolemic agent by combination therapy of the compounds of general formula (I) and β-lactamase inhibitors.

45 **[0010]** Pharmaceutically acceptable salts of this invention are mentioned as follow. As mineral basic salt, sodium or potassium salts of general formula (I) are mentioned. As organic acid salts, succinic acid, maleic acid, toluenesulfonic acid or tartaric acid are mentioned. The compounds of general formula (I) can be orally administered alone or in combination with pharmaceutically acceptable carriers or diluents. They may be administered orally as powders, granules, tablets, capsules by standard pharmaceutical techniques and also parenterally as intrarectal administrations, suppositories and injections.

50 **[0011]** The dosage is ranging from 0.01-1000 mg per day and administered in a single dose or several doses. However, variations will necessarily occur depending upon the conditions, age and body weight of the recipient. Additionally, serum hypocholesterolemic activity is enhanced in the combination with the compounds of the general formula (I) and β-lactamase inhibitors.

**[0012]** The β-lactumase inhibitors such as clavulanic acid are a drug which inhibit to degradation of β-lactum ring by bacteria.

55 **[0013]** The compounds are exemplified as follows, although they did not be limited.

- (1) (4S<sup>+</sup>, 3R<sup>+</sup>)-4-{4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]phenyl}-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-one
- (2) (4S<sup>+</sup>, 3R<sup>+</sup>)-4-(4-[[[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl]phe-

nyl)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl] azetidine-2-one  
 (3) (3S, 2R, 4R, 5R, 6R)-2-[(4-[(4S\*, 3R\*)-1-(4-Fluorophenyl)-3-[3-(4-fluorophenyl)propyl]-2-oxoazetidine-4-yl]phenyl)methyl]-4, 5-diacetyloxy-6-(acetoxymethyl)perhydro-2H-pyran-3-ylacetate  
 (4) (4S\*, 3R\*)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-chlorophenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-one  
 5 (5) (4S\*, 3R\*)-4-(4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-methoxyphenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-one  
 (6) (3S, 2R, 4R, 5R, 6R)-2-[(4-[(4S\*, 3R\*)-1-(4-Methoxyphenyl)-3-[3-(4-fluorophenyl)propyl]-2-oxoazetidine-4-yl]phenyl)methyl]-4, 5-diacetyloxy-6-(acetoxymethyl)perhydro-2H-pyran-3-ylacetate  
 10 (7) (4S\*, 3R\*)-4-(4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-methylphenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-one  
 (8) (3S, 2R, 4R, 5R, 6R)-2-[(4-[(4S\*, 3R\*)-1-(4-Methylphenyl)-3-[3-(4-fluorophenyl)propyl]-2-oxoazetidine-4-yl]phenyl)methyl]-4, 5-diacetyloxy-6-(acetoxymethyl)perhydro-2H-pyran-3-ylacetate  
 (9) (4S\*, 3R\*)-4-(4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-phenyl-3-[3-(4-fluorophenyl)propyl]azetidine-2-one  
 15 (10) (3S, 2R, 4R, 5R, 6R)-2-[(4-[(4S\*, 3R\*)-1-phenyl-3-[3-(4-fluorophenyl)propyl]-2-oxoazetidine-4-yl]phenyl)methyl]-4, 5-diacetyloxy-6-(acetoxymethyl)perhydro-2H-pyran-3-ylacetate  
 (11) (4S\*, 3R\*)-4-(4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-fluorophenyl)-3-[3-(phenyl)propyl]azetidine-2-one  
 20 (12) (4S\*, 3R\*)-4-(4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-fluorophenyl)-3-[2-(4-fluorophenoxy)ethyl]azetidine-2-one  
 (13) (3S, 2R, 4R, 5R, 6R)-2-[(4-[(4S\*, 3R\*)-1-(4-Fluorophenyl)-3-[2-(4-fluorophenoxy)ethyl]-2-oxoazetidine-4-yl]phenyl)methyl]-4, 5-diacetyloxy-6-(acetoxymethyl)perhydro-2H-pyran-3-ylacetate  
 (14) (4S\*, 3R\*)-4-(4-[(4S, 5S, 2R, 3R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methoxy)phenyl)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-one  
 25 (15) (4S\*, 3R\*)-4-(4-[(4S, 5S, 2R, 3R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methoxy)phenyl)-1-(4-fluorophenyl)-3-[2-(4-fluorophenoxy)ethyl]azetidine-2-one  
 (16) (4S\*, 3R\*)-4-(4-[(4S, 5S, 2R, 3R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methoxy)phenyl)-1-phenylmethyl-3-[3-(4-fluorophenyl)propyl]azetidine-2-one  
 30 (17) (2S, 3S, 4R, 5R, 6R)-6-[4-[(4S\*, 3R\*)-1-(4-Fluorophenyl)-3-[3-(4-fluorophenyl)propyl]-2-oxoazetidine-4-yl]phenyl)methyl]-3, 4, 5-trihydroxyperhydro-2H-pyran-2-carboxylic acid  
 (18) 2-{4-[(4S\*, 3R\*)-4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl-3-[3-(4-fluorophenyl)propyl]-2-oxoazetidinyl]phenoxy}-2-methylpropionic acid ethyl ester  
 (19) 2-{4-[(4S\*, 3R\*)-4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl-3-[3-(4-fluorophenyl)propyl]-2-oxoazetidinyl]phenoxy}-2-methylpropionic acid  
 35 (20) 2-{4-[(4S\*, 3R\*)-4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl-3-[3-(4-methylphenyl)propyl]-2-oxoazetidinyl]phenoxy}-2-methylpropionic acid ethyl ester  
 (21) 2-{4-[(4S\*, 3R\*)-4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl-3-[3-(4-methylphenyl)propyl]-2-oxoazetidinyl]phenoxy}-2-methylpropionic acid  
 40 (22) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-fluorophenyl)azetidine-2-one  
 (23) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-phenylazetidine-2-one  
 (24) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-methylphenyl)azetidine-2-one  
 45 (25) (4S, 3R)-4-(4-[(5S, 2R, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-one  
 (26) (4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)-3-oxopropyl]azetidine-2-one  
 50 (27) (4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-phenyl-3-[3-(4-fluorophenyl)-3-oxopropyl]azetidine-2-one  
 (28) (4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-methylphenyl)-3-[3-(4-fluorophenyl)-3-oxopropyl]azetidine-2-one  
 (29) 4-[(4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl]-2-oxoazetidinyl]benzoic acid  
 55 (30) 4-[(4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-3-[3-(4-fluorophenyl)-3-oxopropyl]-2-oxoazetidinyl]benzoic acid  
 (31) 4-[(4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-3-[3-(4-fluorophenyl)-3-oxopropyl]-2-oxoazetidinyl]benzoic acid

phenyl)-3-[3-(4-fluorophenyl)propyl]-2-oxoazetidinyl]benzoic acid

(32) 3-[(2E)-3-(4-Fluorophenyl)-2-propenyl](4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-fluorophenyl)azetidine-2-one

(33) (4S, 3R)-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]phenyl]-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-one

(34) (4S, 3R)-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]phenyl]-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)-3-oxopropyl]azetidine-2-one

(35) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]phenyl]-1-(4-fluorophenyl)azetidine-2-one

(36) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]phenyl]-1-(4-methylphenyl)azetidine-2-one

(37) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]-1-phenylazetidine-2-one

(38) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-1-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-fluorophenyl)azetidine-2-one

(39) (4S, 3R)-3-[(3S)-3-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl]-3-hydroxypropyl]-1-phenyl-4-(4-fluorophenyl)azetidine-2-one

(40) (4R\*, 3R\*)-4-[(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-3-[3-(4-fluorophenyl)propyl]-1-(4-fluorophenyl)azetidine-2-one

(41) 3-[(3S)-3-Hydroxy-3-phenylpropyl](4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-phenylazetidine-2-one

(42) 4-[3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl](4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-2-oxoazetidinyl]benzoic acid ethyl ester

(43) 4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl]phenyl)(4S, 3R)-1-(4-methylphenyl)-3-[3-(4-fluorophenoxy)ethyl]azetidine-2-one

(44) 3-(3-Phenylpropyl)(4S, 3R)-4-(4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-phenylazetidine-2-one

(45) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]ethene]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(46) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]ethyl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(47) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]-1-propen-3-yl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(48) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]propyl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(49) 3-[(3S)-4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-Trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]phenyl]-3-hydroxypropyl(4S, 3R)-1,4-bis(4-fluorophenyl)azetidine-2-one

(50) (4S, 3R)-3-[(3S)-3-(4-fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methoxypropyl-3-yl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(51) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methoxy-2-propen-3-yl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(52) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]-1-buten-4-yl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(53) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]butyl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(54) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]-1-penten-5-yl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(55) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]pentyl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

(56) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]ethyl-2-yl]phenyl)-1-phenylazetidine-2-one

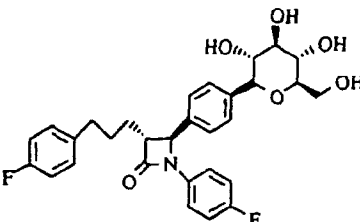
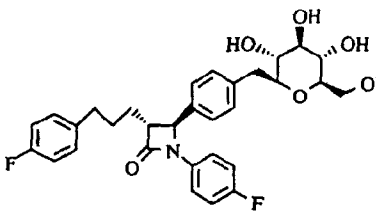
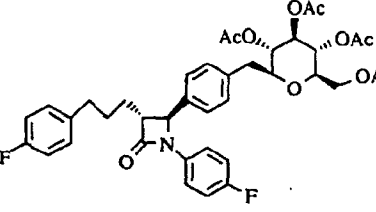
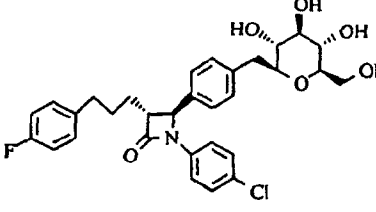
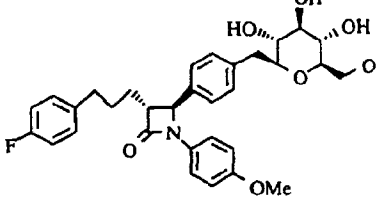
(57) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]ethyl-2-yl]phenyl)-1-(4-methylphenyl)azetidine-2-one

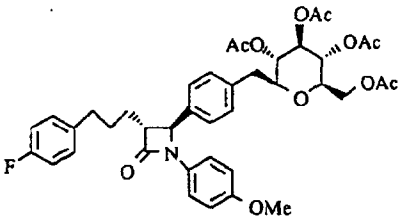
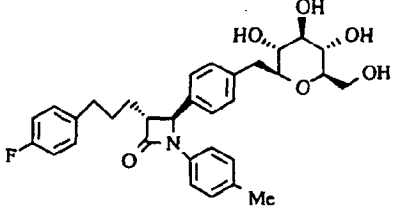
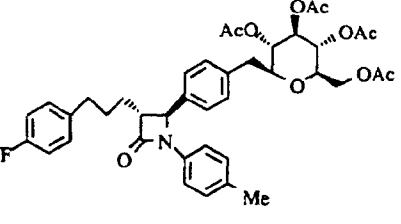
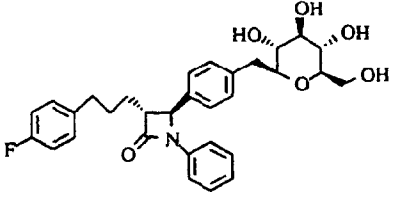
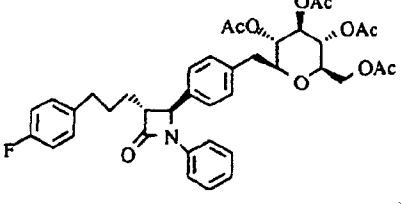
(58) (4S, 3R)-3-[(3S)-3-(4-Fluorophenyl)-3-hydroxypropyl]-4-[4-[(2S, 5S, 3R, 4R, 6R)-3, 4, 5-trihydroxy-6-(carboxyl)perhydro-2H-pyran-2-yl]ethyl-2-yl]phenyl)-1-(phenyl)azetidine-2-one

**[0014]** Typical preparation of the compounds according to the invention are shown, but they are not limited to these compounds. The compounds showing the specific rotation are either prepared as the optically active compound or

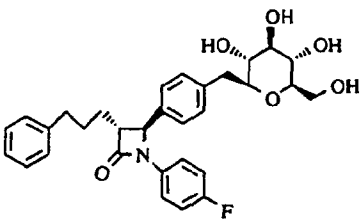
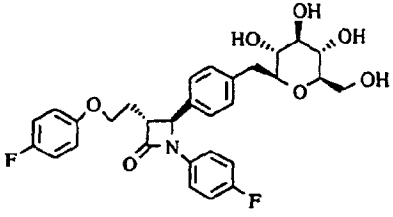
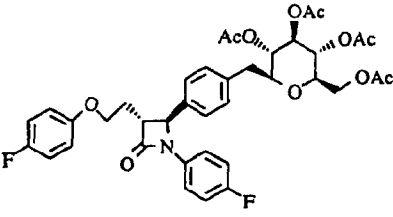
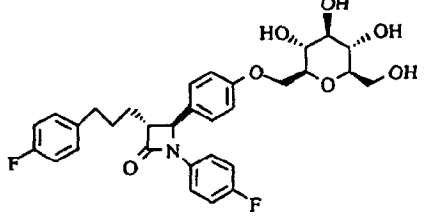
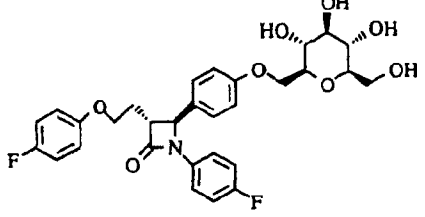
separated as optically active compounds by the suitable methods and determined the specific rotation.

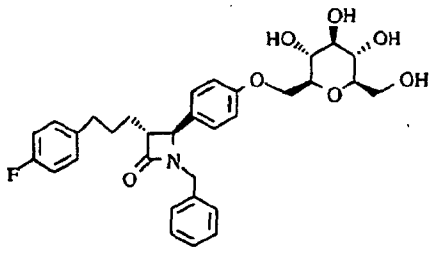
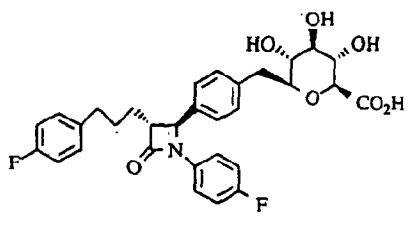
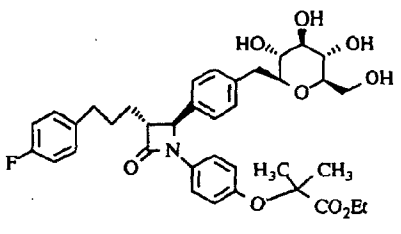
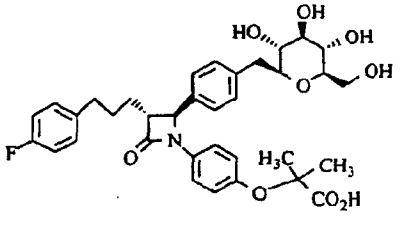
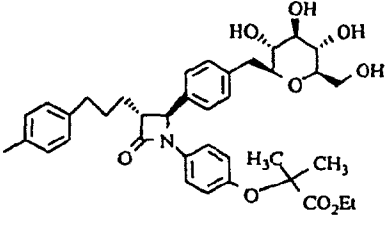
The compound of general formula (I) can be obtained as follows.

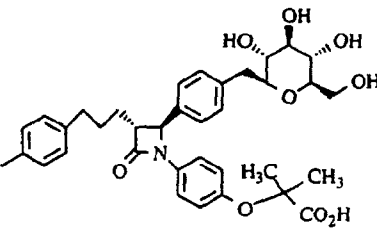
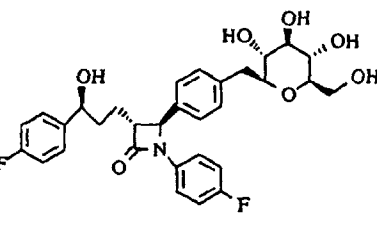
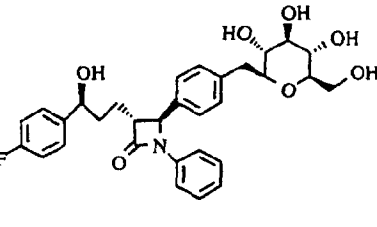
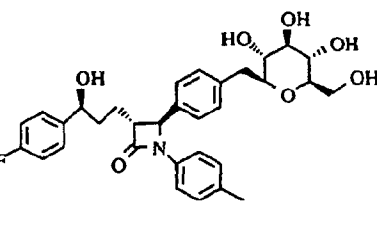
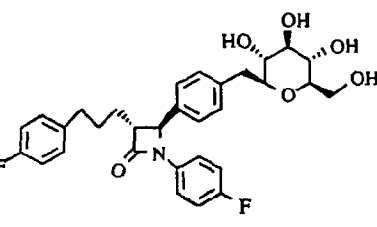
No.	Structure	mp (°C)	$[\alpha]_D^{25} / (C, \text{Solv.})$
1		89-90	-40.4 (C=0.5, MeOH)
2		110-112	-33.2 (C=0.5, MeOH)
3		56-58	
4		76-78	
5		73-75	

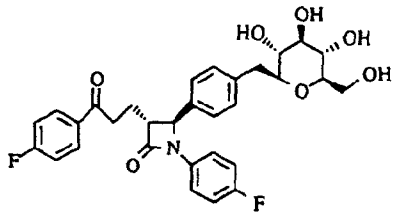
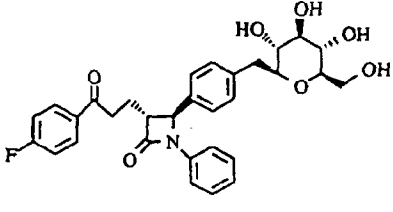
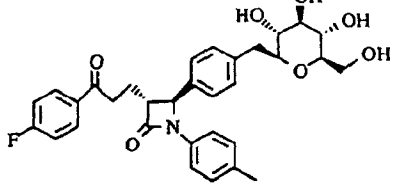
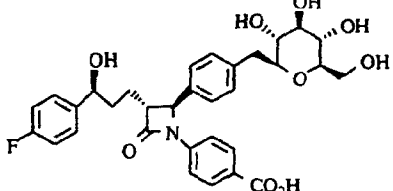
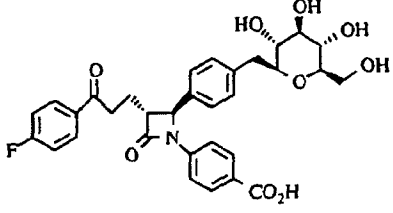
No.	Structure	mp (°C)	$[\alpha]_D^{25} / (C, \text{Solv.})$
6		60-62	/
7		80-82	-46.7 (C=0.3, MeOH)
8		56-58	/
9		84-86	-40.4 (C=0.5, MeOH)
10		60-61	/

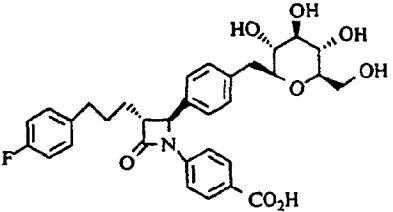
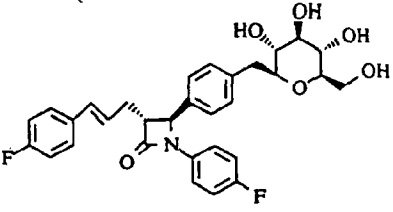
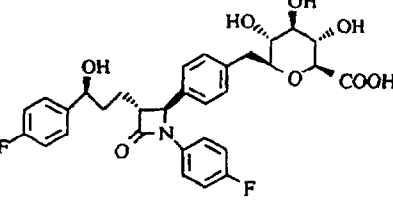
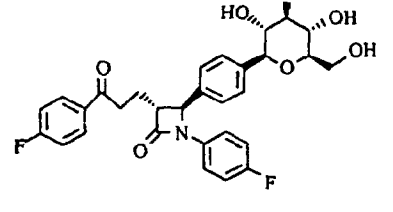
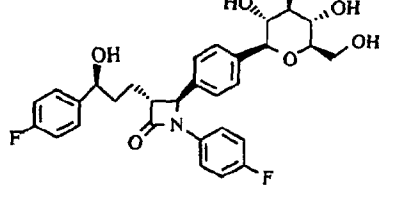


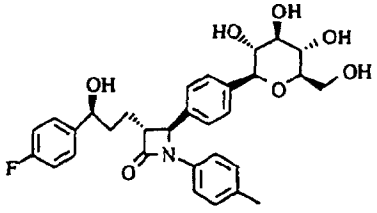
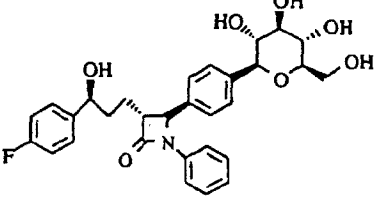
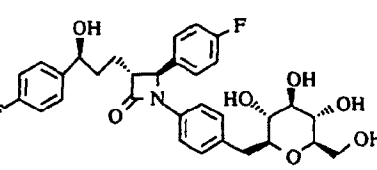
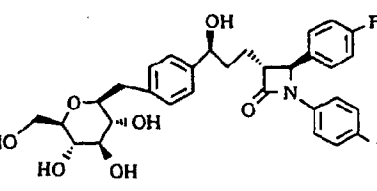
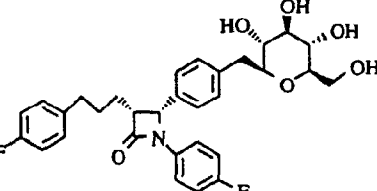
No.	Structure	mp (°C)	$[\alpha]_D^{25} / (C, \text{Solv.})$
11		74-75	
12		65-67	-40.4 (C=0.5, CHCl <sub>3</sub> )
13		64-66	
14		61-62	
15		64-65	

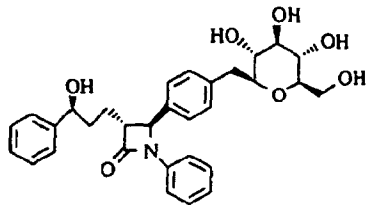
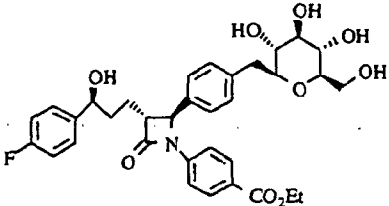
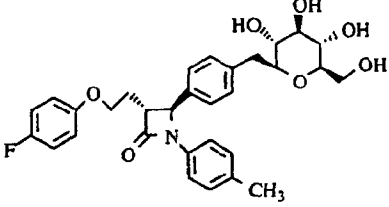
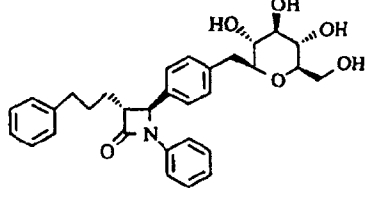
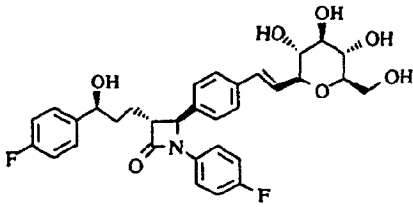
No.	Structure	mp (°C)	$[\alpha]_D^{25} / (C, \text{Solv.})$
16		73-75	
17		105-106	
18		73-74	
19		170-172	
20		76-78	

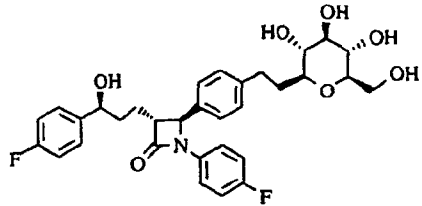
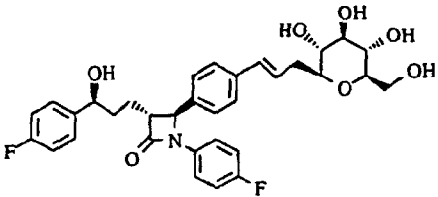
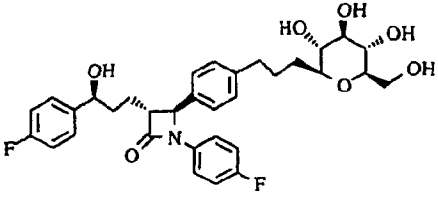
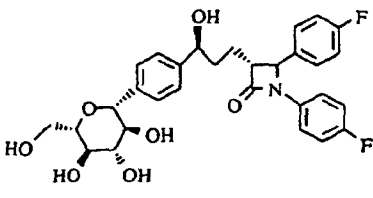
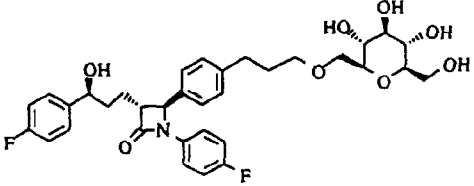
No.	Structure	mp (°C)	$[\alpha]_D^{25} / (C, \text{Solv.})$
21		161-162	/
22		115-117	-71.3 (C=0.3, MeOH)
23		104-106	-110 (C=0.5, MeOH)
24		102-104	-58.0 (C=0.3, MeOH)
25		67-69	-62.8 (C=0.5, MeOH)

No.	Structure	mp (°C)	$[\alpha]_D^{25}$ / (C, Solv.)
26		78-80	-67.2 (C=0.5, MeOH)
27		104-106	-26.0 (C=0.5, MeOH)
28		86-88	-35.7 (C=0.6, MeOH)
29		148-150	-122.0 (C=0.3, MeOH)
30		102-104	-52.0 (C=0.3, MeOH)

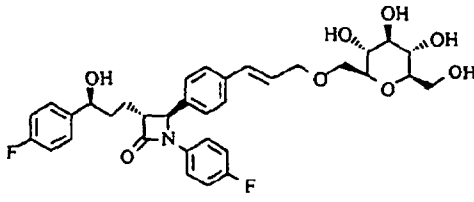
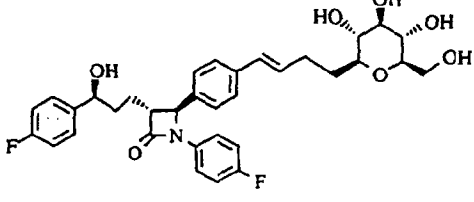
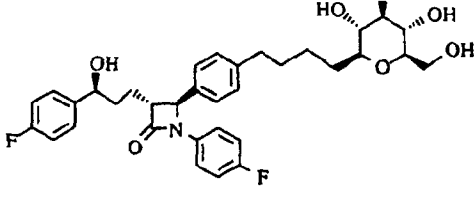
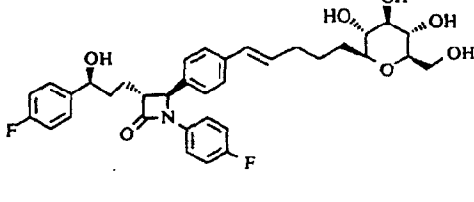
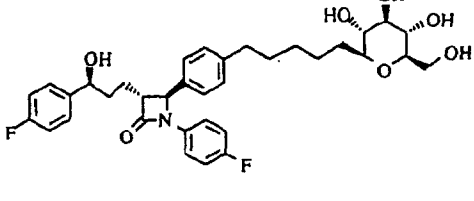
No.	Structure	mp (°C)	$[\alpha]_D^{25} / (C, \text{Solv.})$
31		97-99	
32		liq	-39.3 (C=0.8, MeOH)
33		82-84	-47.6 (C=0.5, MeOH)
34		83-85	
35		81-83	

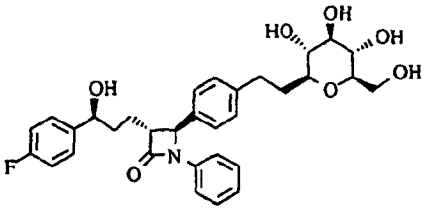
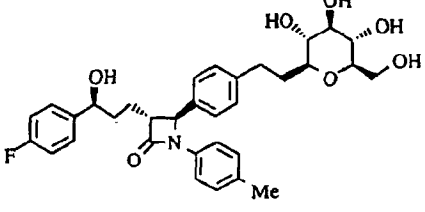
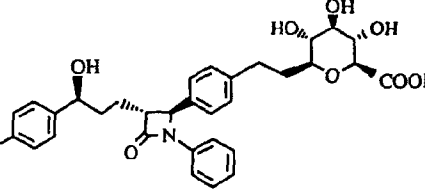
No.	Structure	mp (°C)	$[\alpha]_D^{25}$ / (C, Solv.)
36		79-81	
37		80-82	
38		200-201	-69.3 (C=0.3, MeOH)
39		126-128	-42.66 (C=0.3, MeOH)
40		78-80	

No.	Structure	mp (°C)	$[\alpha]_D^{25}$ / (C, Solv.)
41		110-112	-67.2 (C=0.5, MeOH)
42		56-58	-92.0 (C=0.3, MeOH)
43		96-98	-40.4 (C=0.5, CHCl <sub>3</sub> )
44		84-86	-41.3 (C=0.3, MeOH)
45		84-86	-64.0 (C=0.25, MeOH)

No.	Structure	mp (°C)	$[\alpha]_D^{25}$ / (C, Solv.)
46		153-155	-54.66 (C=0.25, MeOH)
47		72-74	-33.6 (C=1.0, MeOH)
48		81-83	-21.8 (C=1.0, MeOH)
49		111-113	-20.0 (C=0.35, MeOH)
50		61-63	-48.6 (C=0.14, MeOH)



No.	Structure	mp (°C)	$[\alpha]_D^{25} / (C, \text{Solv.})$
51		65-67	-42.8 (C=0.25, MeOH)
52		79-81	-33.2 (C=1.0, MeOH)
53		81-83	-29.4 (C=0.5, MeOH)
54		69-71	-38.6 (C=0.35, MeOH)
55		66-68	-42.9 (C=0.35, MeOH)

No.	Structure	mp (°C)	$[\alpha]_D^{25} / (C, \text{Solv.})$
56		82-84	-49.2 (C=1.0, MeOH)
57		116-118	-76.0 (C=0.3, MeOH)
58		110-112	-40.3 (C=0.7, MeOH)

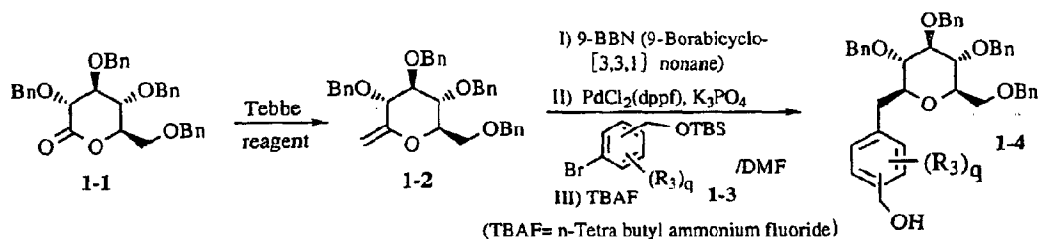
Method 1

[0015]

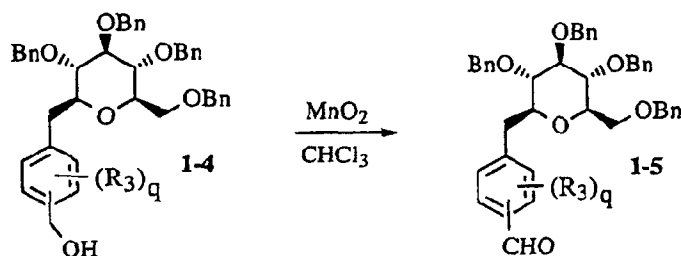
(1)

(a) In case of  $R_4$  is  $-\text{CH}_2-$  in the compounds of general formula (I), the compound is prepared by the following reactions.

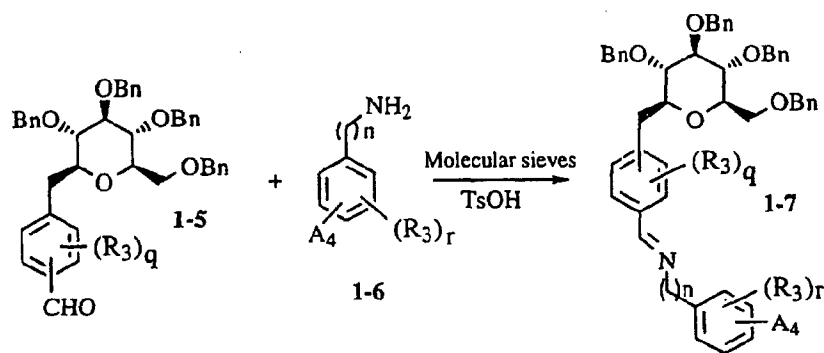
The compound (1-2) obtained by a reaction of tetrabenzyl glucuronolactone (1-1) with Tebbe reagent (T. V. Rajanbabu et al., J.Org.Chem. 1986, 51, 5458), is used as a starting material. The compound (1-2) is subjected to Suzuki coupling reaction with the compound (1-3) (C.R. Johnson et al., Synlett 1997, 1406) followed by desilylation to yield the compound (1-4).



(b) The compound (1-5) is obtained by oxidation of the hydroxyl group of compound (1-4) to obtain the aldehyde compound (1-5).

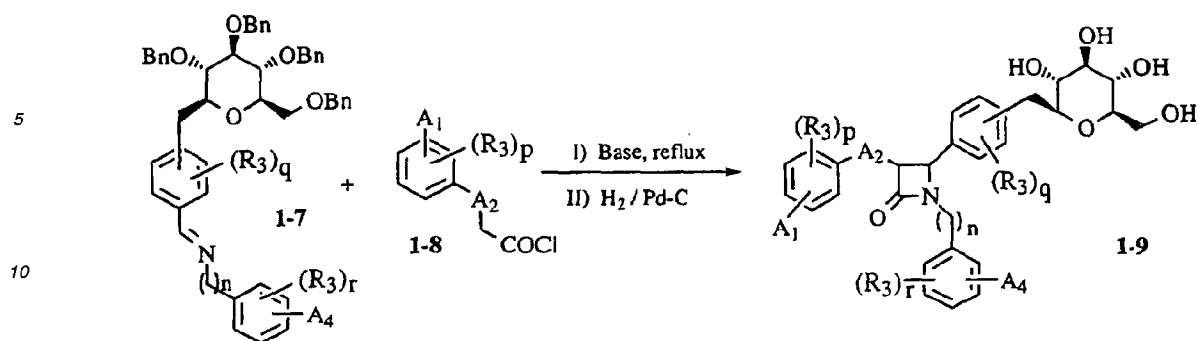


(c) The aldehyde compound (1-5) and the amine compound (1-6) are condensed in the presence of a molecular sieves and p-toluenesulfonic acid to obtain the compound (1-7).

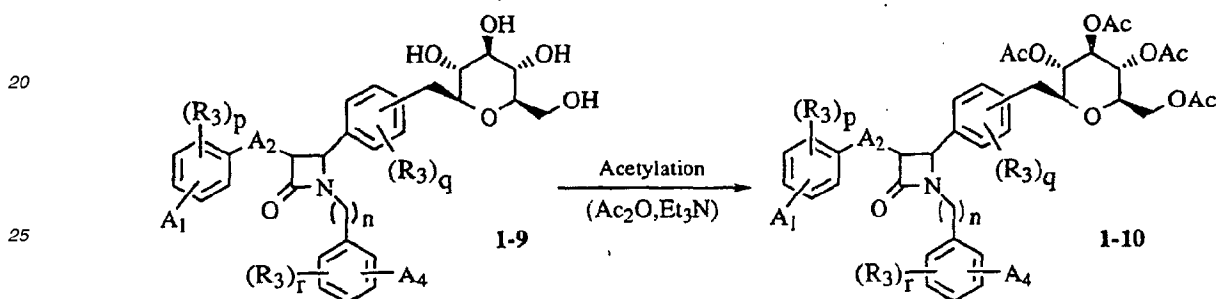


The imine compound (1-7) and the compound (1-8) are subjected to Staudinger reaction by refluxing in the presence of base to yield a  $\beta$ -lactam compound. In this reaction, when tri-n-butyl amine is used as the base, the trans  $\beta$ -lactam compound is obtained. When LDA (lithium diisopropyl amide) is used as the base, the cis  $\beta$ -lactam compound is obtained.

Furthermore, the asymmetric  $\beta$ -lactam compound can be also obtained by addition of a chiral ligand in the reaction mixture (A.M. Hafez et al., Org. Lett. 2000, 2(25), 3963-3965). Subsequently, the debenzylated compound (1-9) is obtained by catalytic hydrogenation.



15 (d) The compound (1-10) is obtained by an acetylation of the compound (1-9).



30 (2) In case of  $R_4$  is  $-\text{CH}_2-$  in the compounds of general formula (I), the compound is prepared by the following reactions.

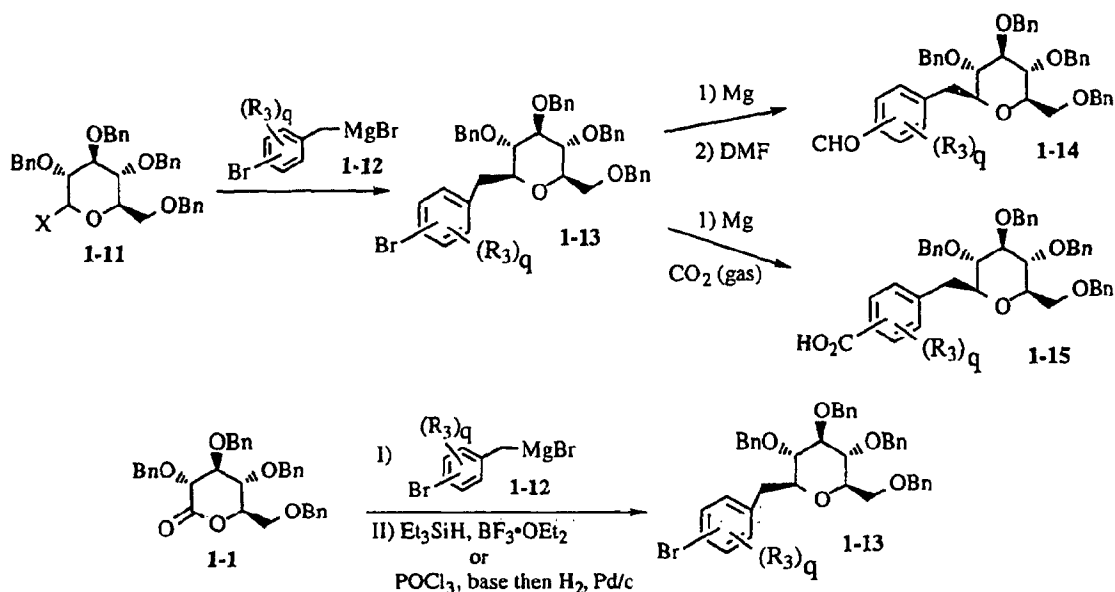
35 The compound (1-11) is reacted with Grignard reagent (1-12) to yield the compound (1-13) (M. F. Wong et al., J. Carbohydr. Chem. 1996, **15**(6), 763 ; C. D. Hurd et al., J. Am. Chem. Soc. 1945, **67**, 1972 ; H. Togo et al., Synthesis 1998, 409). Alternatively, the compound (1-11) is reacted with Grignard reagent (1-12) followed by dehydroxylation with triethylsilyl hydride. The generated hydroxyl group is converted to a leaving group such as tosyl group or halogen and the resulting compound is reacted with base to yield the olefin compound. Then the compound (1-13) is obtained by hydrogenation of the olefin compound. The compound (1-13) is converted to Grignard reagent with magnesium metal and reacted with DMF (dimethylformamide) to yield the compound (1-14). The compound (1-15) is obtained by the reaction of Grignard reagent of the compound (1-13) with dry-ice ( $\text{CO}_2$ ).

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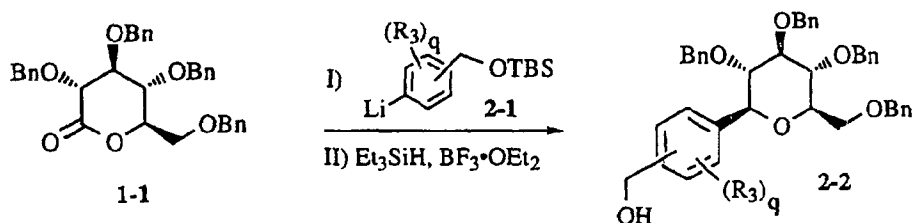
The compound (1-14) and the compound (1-15) which are obtained as above mentioned are the synthetic intermediates of the general formula (I) according to the Method 1-(1)-(c) and (d).

#### Method 2

#### [0016]

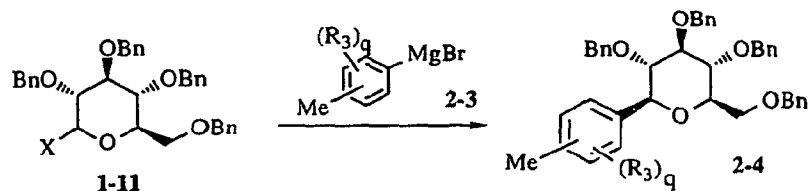
(1) In case of R<sub>4</sub> is a directly connected bond in the compounds of general formula (I), the compound is prepared by the following reactions.

Tetrabenzylglucuronolactone (1-1) is reacted with the compound (2-1) followed by the reaction with Et<sub>3</sub>SiH and BF<sub>3</sub>·Et<sub>2</sub>O to provide the compound (2-2) (J.M. Lancelin et al., *Tetrahedron Lett.* 1983, **24**, 4833). The compound (2-2) is the synthetic intermediates of the general formula (I) according to the method 1-(1)-(b), (c), and (d).



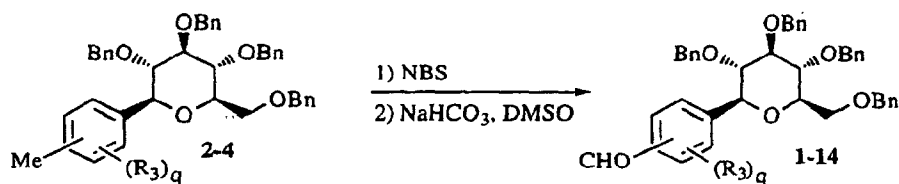
(2) In case of R<sub>4</sub> is a directly connected bond in the compounds of general formula (I), the compound is prepared by the following reactions.

The compound (2-4) is obtained by the reaction of the compound (1-11) with Grignard reagents (2-3) (F. Marquez et al., *An. Quim., Ser. C.* 1983, **79**(3), 428).

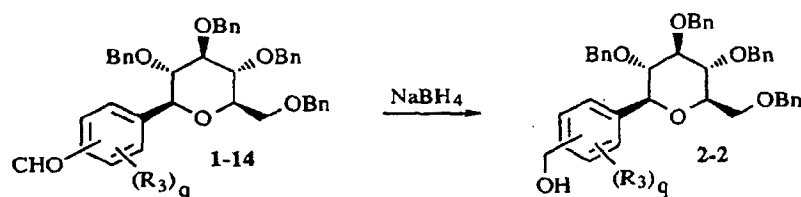


(wherein X is mentioned above)

**[0017]** The compound (1-14) is obtained by conversion of the methyl group of the compound (2-4) to the aldehyde compound (P. S. Portoghese et al., J. Med. Chem. 2000, **43**, 2489).



**[0018]** The compound (2-2) is obtained by reduction of the compound (1-14) with NaBH<sub>4</sub>.

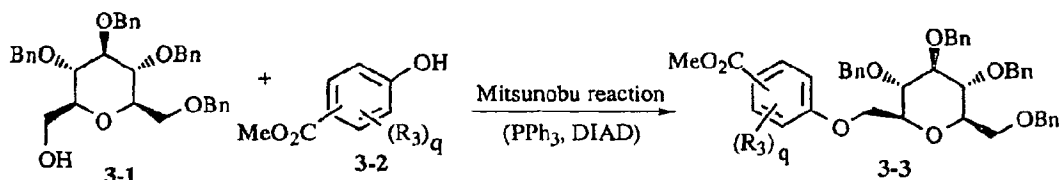


Method 3

**[0019]**

(1) In case of R<sub>4</sub> is -OCH<sub>2</sub>- in the compounds of general formula (I), the compound is prepared by the following reactions.

(a) The compound (3-1) prepared by the known method (D. Zhai et al., J. Am. Chem. Soc. 1988, **110**, 2501.; P. Allevi et al., J. Carbohydr. Chem. 1993, **12**(2), 209) is subjected to Mitsunobu reaction with the compound (3-2) to provide the compound (3-3).



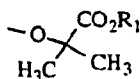
(b) The compound (3-4) is obtained by reduction of the methylester group of the compound (3-3) to the alcohol group with LiAlH<sub>4</sub>.



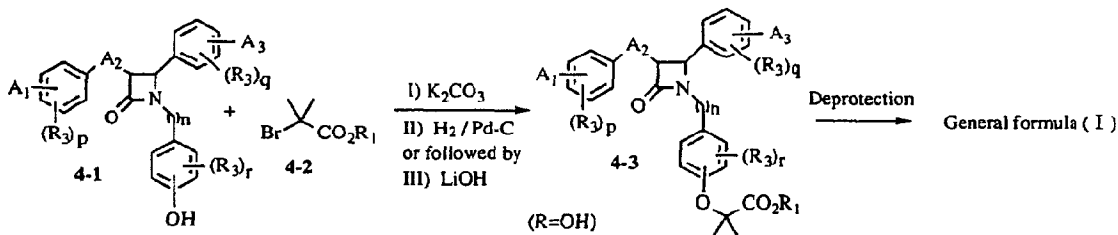
**[0020]** The compound (3-4) is the synthetic intermediates of the general formula (I) according to the method 1-(1)-(b), (c), and (d).

#### Method 4

**[0021]** In case of that one of A<sub>1</sub>, A<sub>3</sub>, and A<sub>4</sub> is the following compound in the compounds of general formula (I), the compound is prepared by the following reactions.



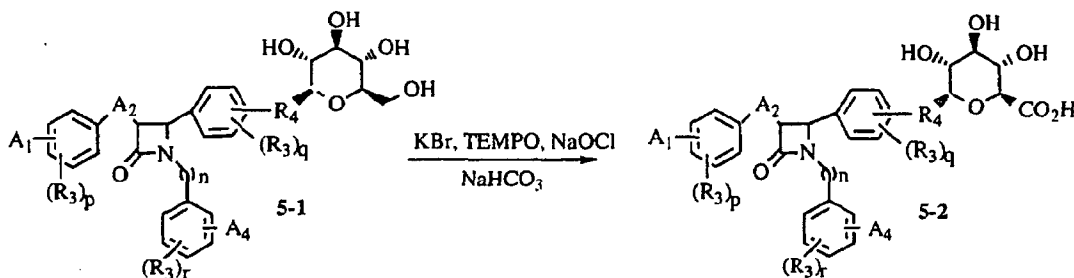
**[0022]** The compound (4-1) is reacted with 2-bromoisolactic acid alkylester (4-2) in the presence of  $K_2CO_3$  followed by hydrogenation to yield the compound of general formula (I). Alternatively, the compound (4-3) is obtained by hydrolysis with lithium hydroxide and followed by the deprotection to provide the compound of general formula (I).



### Method 5

**[0023]** In case of R<sub>2</sub> is -CO<sub>2</sub>H in the compounds of general formula (I), the compound is prepared by the following reactions.

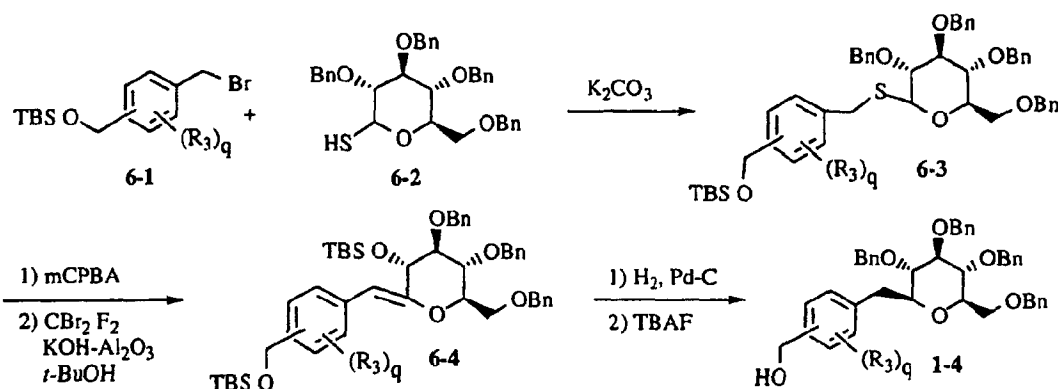
**[0024]** The compound (5-1) is oxidized with TEMPO (2, 2, 6, 6-tetramethyl-1-piperidinyloxy, free radical) to yield the compound (5-2).



### Method 6

**[0025]** The compound (6-3) is obtained by the reaction of the compound (6-1) and (6-2). The compound (6-3) is oxidized to the sulfone compound followed by Ramberg-Bäcklund reaction (P. S. Belica et. al., *Tetrahedron Lett.* **1998**,

39, 8225. ; F.K.Griffin et al., Tetrahedron Lett. 1998, 39, 8179) to afford the compound (6-4). The compound (6-4) is hydrogenated followed by a reaction with TBAF to provide the compound (1-4). The compound (1-4) can be used as synthetic materials to obtain general formula (I) according to the method 1.

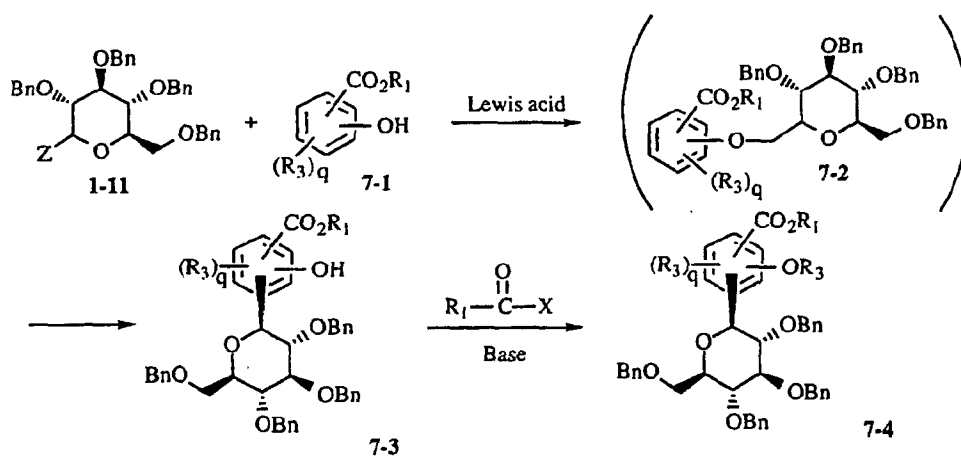


#### Method 7

#### [0026]

(1) In case of  $R_3$  is -OH- and -OC(O) $R_1$  in the compounds of general formula (I), the compounds are prepared by the following reactions.

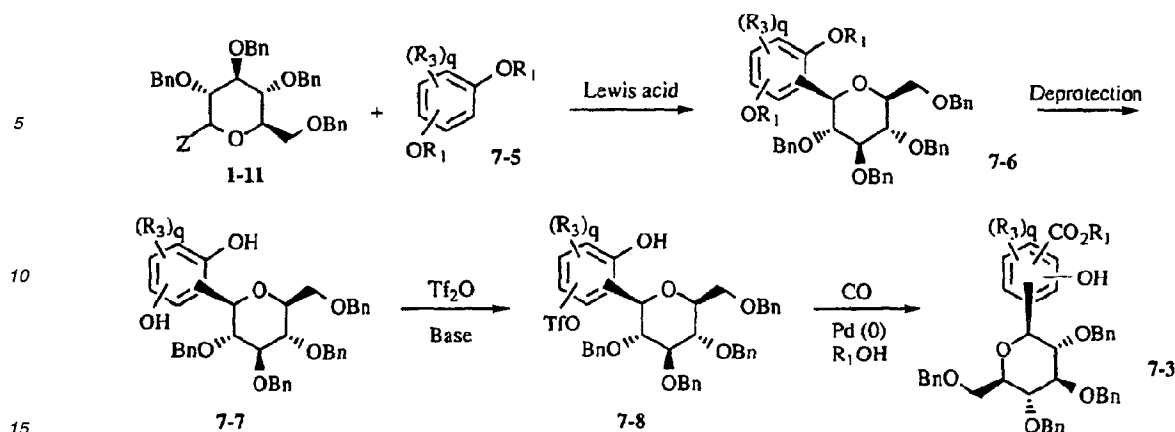
The compound (7-3) is obtained by glycosidation of the compound (7-1) with the compound (1-11) in the presence of Lewis acid ( $\text{BF}_3 \cdot \text{Et}_2\text{O}$ ,  $\text{SnCl}_4$ ,  $\text{AgOTf} \cdot \text{Cp}_2\text{HfCl}_2$ , etc) (R.R.Schmidt et al., Synthesis 1993, 325). The reaction proceed in 2 steps, first step is O-glycosidation and second step is O-glycoside rearrngment to C-glycoside. Futhermore, the compound (7-3) can be converted to the compound (7-4) by esterification of the phenolic hydroxyl group. The compound (7-3) and (7-4) can be used as the synthetic materials to obtain general formula (I) according to the method 1 and 3.



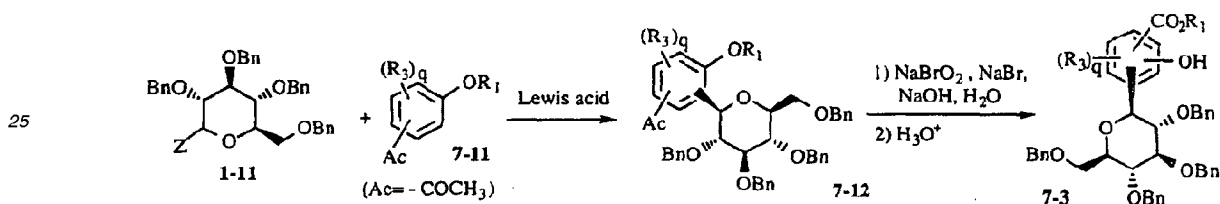
(2) In case of  $R_3$  is -OH- and -OC(O) $R_1$  in the compounds of general formula (I), the compounds are prepared by the following reactions.

The compound (7-6) obtained by the same procedure of method 7-(1) is deprotected to obtain the compound (7-7). One of the hydroxyl group of the compound is triflated, followed by a reaction of carbene monooxide to give the compound (7-3) (R. E. Dolle et al, Chem. Commun. 1987, 904). The compound (7-3) is used as the starting material of general formula (I) according to the method 7-(1), 1 and 3.



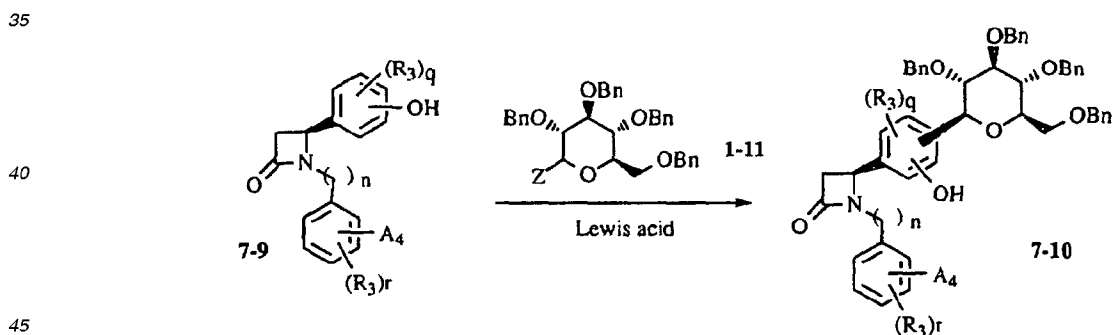


The compound (7-3) is also obtained by the same coupling reaction of the compound (7-11) with the compound (1-11) to obtain the compound (7-12) followed by Haloform reaction of the acetyl group to obtain the compound (7-3) (S. Kajigaeshi et al., Synthesis 1985, 674).



(3) In case of  $R_3$  is -OH- and -OC(O) $R_1$  in the compounds of general formula (I), the compounds are prepared by the following reaction.

The compound (7-10) is obtained by the aryl C-glycosidation of the compound (7-9) according to the method 7(1). The compound (7-10) is used as a starting material of general formula (I) according to the method 8.

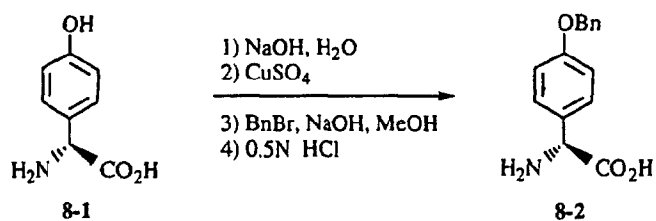


(wherein Z is same as mentioned above.)

#### Method 8

**[0027]** The preparative methods of the optically active compounds (I).

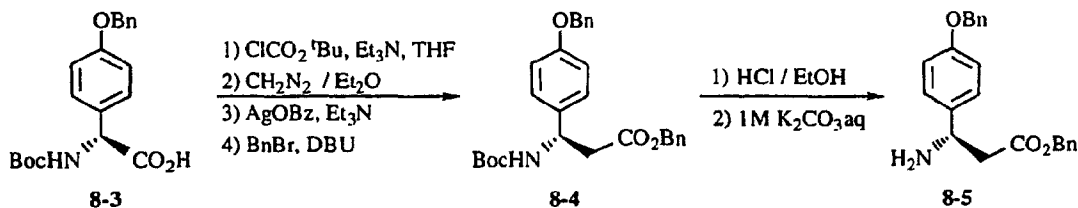
(a) Benzylation of the hydroxy group of D-p-hydroxyphenylglycine (8-1) provides the compound (8-2) using E. Wunsch's method (Chem. Ber. 1958, 91,543).



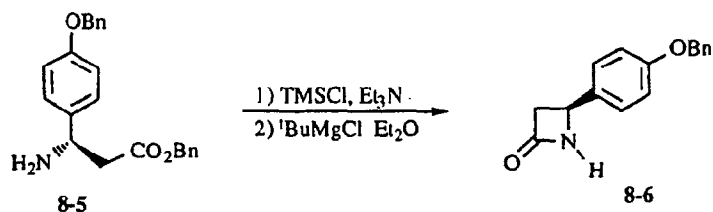
The compound (8-3) is obtained by the protection of the amino group of the compound (8-2) with Boc group.



The compound (8-3) is converted to the compound (8-4) by homologation (W. W. Ogilvie et al., Bioorg. Med. Chem. 1999, 7,1521). Then, the compound (8-5) is obtained by deprotection of the Boc group of the compound (8-4).

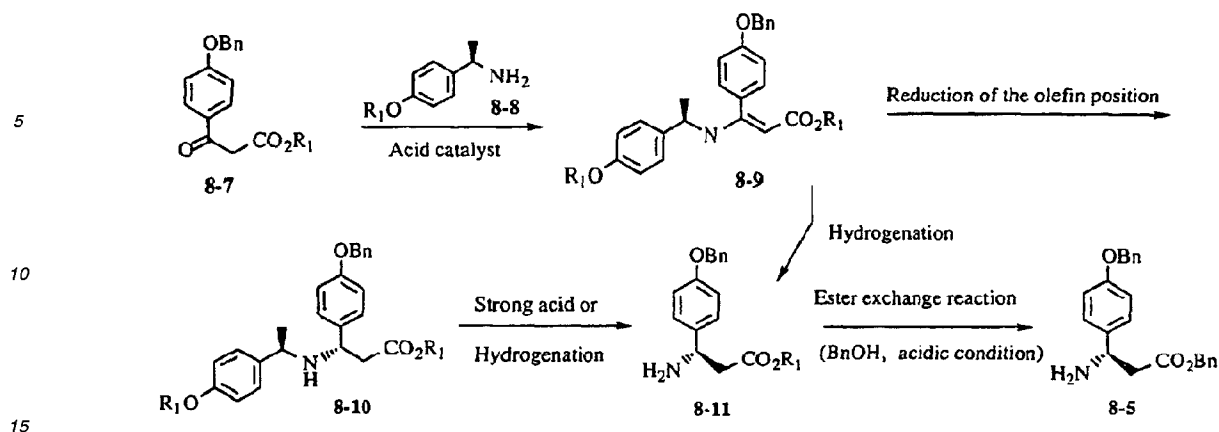


Cyclization of the compound (8-5) provides the  $\beta$ -lactam (8-6) using W.W.Ogilvie's method (W. W. Obilvie et al., Bioorg. Med. Chem. 1999, 7,1521).

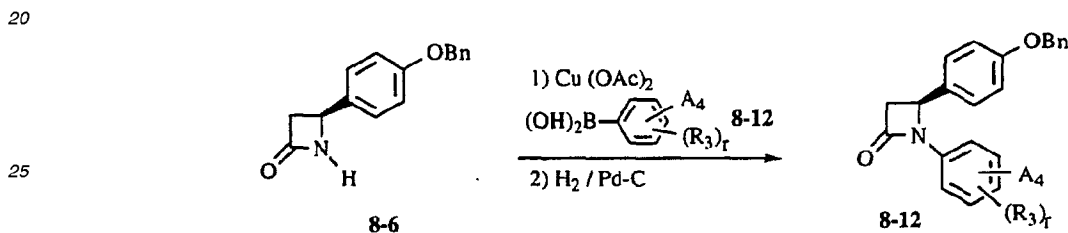


The compound (8-5) is also obtained by following method as the optically active compound.

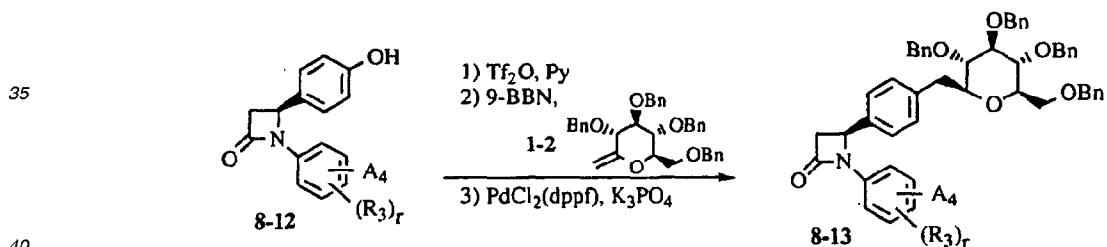
Namely, the compound (8-9) is obtained by the reaction of the compound (8-7) with the optically active amino acid derivatives (8-8) in the presence of acid catalyst. The compound (8-9) is directly reduced to the compound (8-11). The compound (8-11) is also obtained by a reduction of olefin (ex.  $NaBH(OAc)_3$ ,  $NaBH_4$ ) and treated with strong acid (ex.  $HCO_2H$ ,  $Et_3SiH$ ) (C.Cimarelli et al., J.Org.Chem. 1996, 61,5557) or hydrogenolysis. The compound (8-11) provides the compound (8-5) by an ester exchange reaction with  $BnOH$ . The compound (8-5) can be converted to the compound (8-6) by the same method as above mentioned.



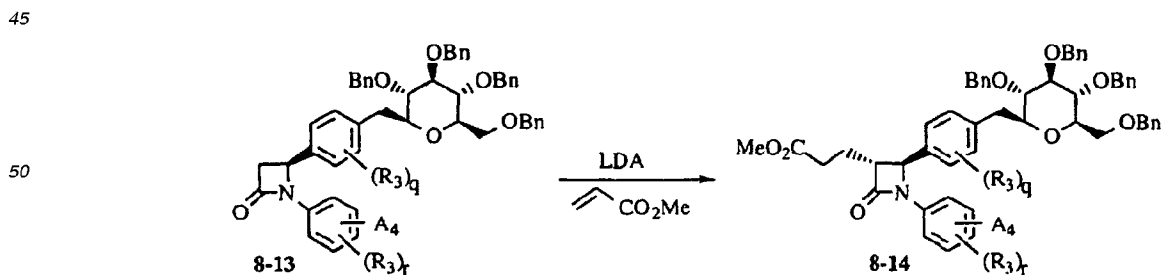
The  $\beta$ -lactam compound (8-6) is N-alkylated by D.M.T.Chan's method (Tetrahedron Lett. 1998, 39,2933), followed by debenzoylation to afford the compound (8-12).



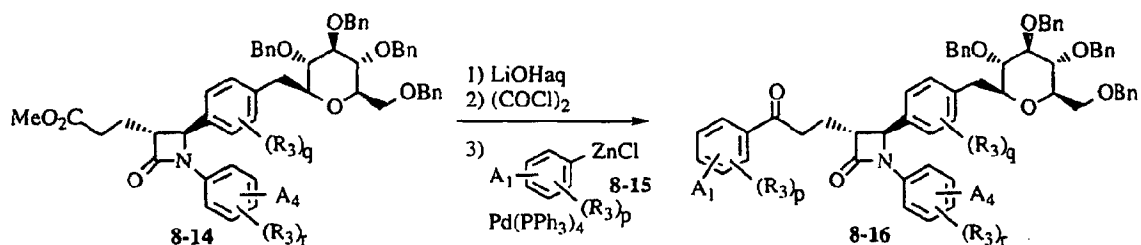
The compound (8-13) is obtained by Suzuki coupling reaction of the compound (8-12) and the glucose derivatives (1-2) according to C. R. Johnson's method (C. R. Johnson et al., synlett 1997, 1406).



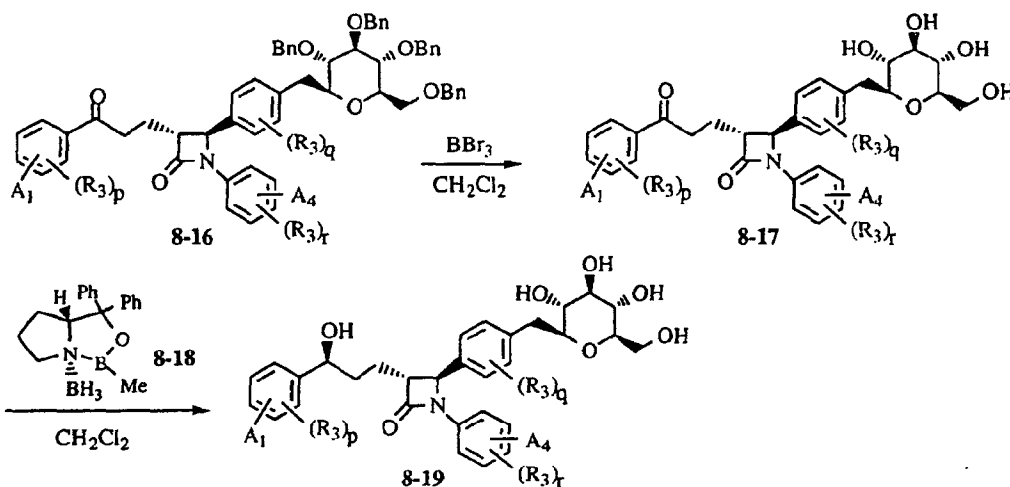
The compound (8-13) is reacted with LDA, followed by C-alkylation with methyl acrylate to provide the compound (8-14).



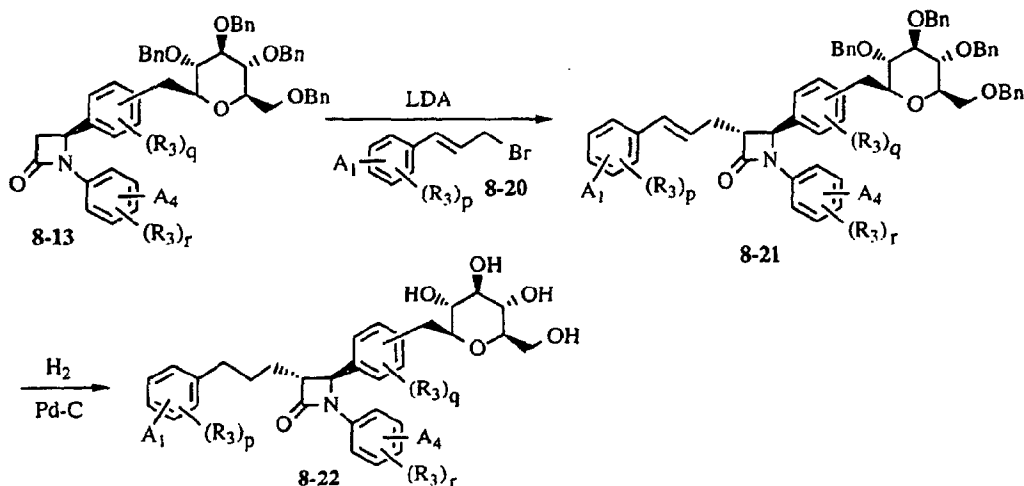
The conversion of ester group of the compound (8-14) to the acid chloride, and coupling with the compound (8-15) using Negishi's method and obtained the compound (8-16).



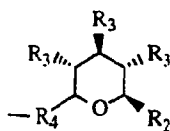
10 The compound (8-16) is debenzylated to the compound (8-17) and followed by asymmetric reduction of the ketone group of the compound (8-17) by E. J. Corey's method (E. J. Corey et al., J. Am.Chem.Soc. 1987, 109, 7925).



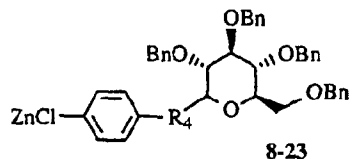
25 (b) The compound (8-13) is reacted with LDA, followed by the reaction with the compound (8-20) to provide the compound (8-21). The compound (8-22) is obtained by hydrogenation of the compound (8-21).



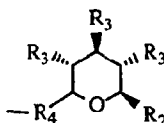
35 [0028] In case of A<sub>1</sub> in the general formula (I) is the following compound,



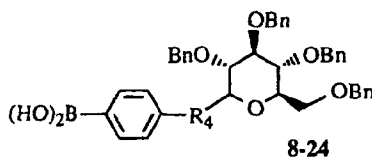
for example, according to the method 8, the compound 39 is prepared from the following compound (8-23) which correspond to the compound (8-15).



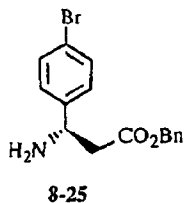
[0029] In case of A<sub>4</sub> in the general formula (I) is the following compound,



for example, according to the method 8, the compound 38 is prepared from the following compound (8-24) which correspond to the compound (8-12).



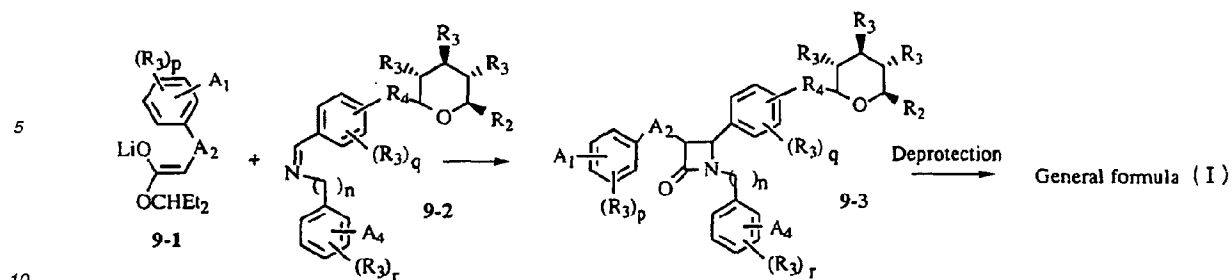
[0030] The compound (8-25) is also obtained by enzymatic separation of a racemic compound (S.J.Faulconbridge et al., Tetrahedron Lett., 2000, 41, 2679). The compound (8-25) can be converted to general formula (2) by Suzuki coupling as above mentioned.



#### Method 9

[0031] The preparative method of the optically active compounds (II).

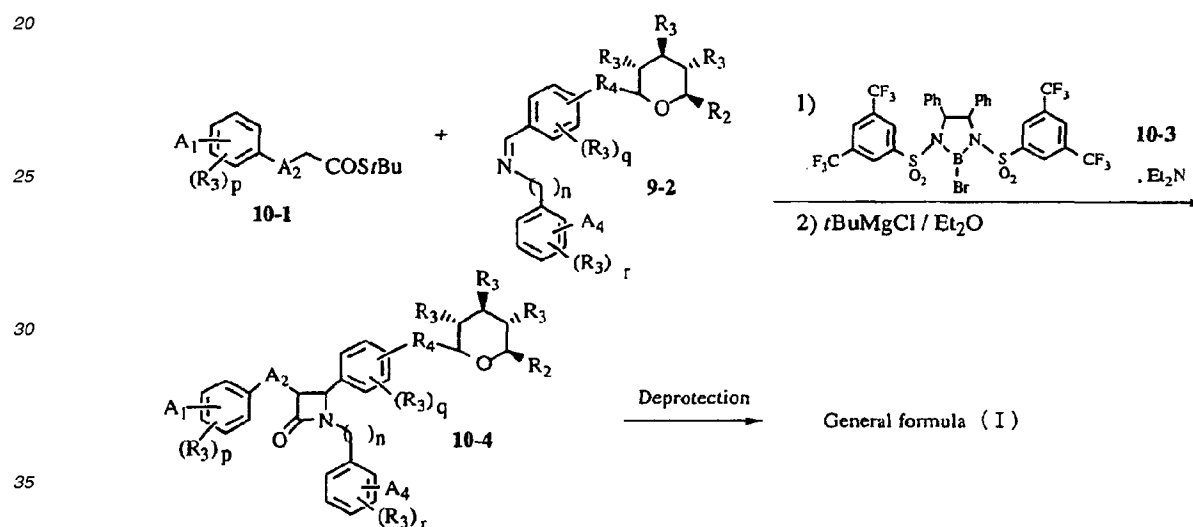
[0032] The compound (9-1) is condensed with the compound (9-2) to provide the compound (9-3) by K. Tomioka's method (K. Tomioka et al., J. Chem. Soc., Chem. Commun. 1999, 715). The compound of general formula (I) is obtained by deprotection of the compound (9-3). The compound (9-3) is also obtained by the reaction of the silyl enol ether with Lewis acid instead of the compound (9-1).



## Method 10

[0033] The preparative method of the optically active compounds (III).

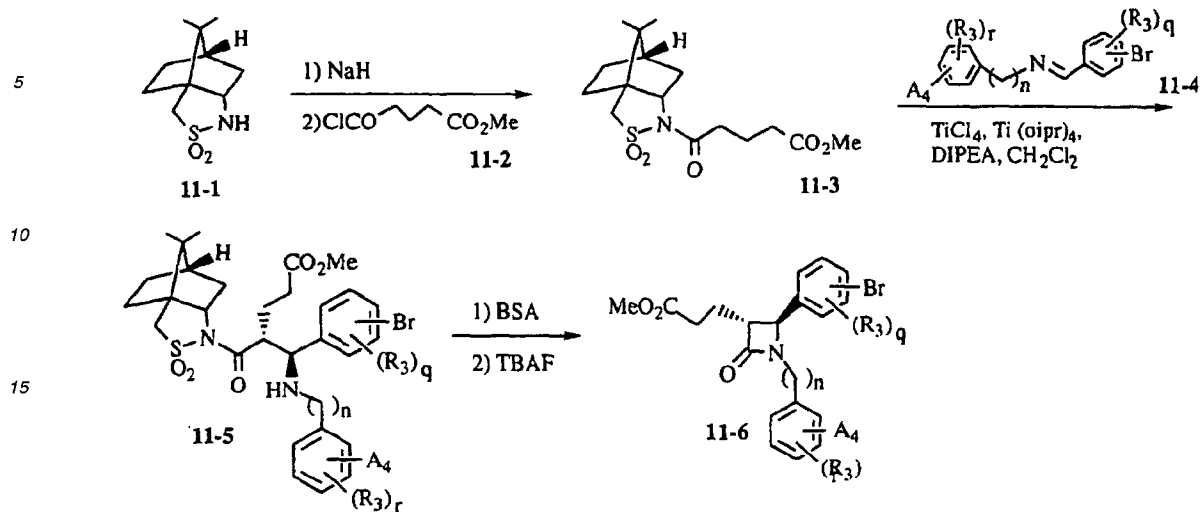
[0034] The compound (10-1) is condensed with the compound (9-2) to provide the compound (10-4) by E. J. Corey's method (E. J. Corey et al., *Tetrahedron Lett.* 1991, **32**, 5287). The compound of general formula (I) is obtained by deprotection of the compound (10-4).



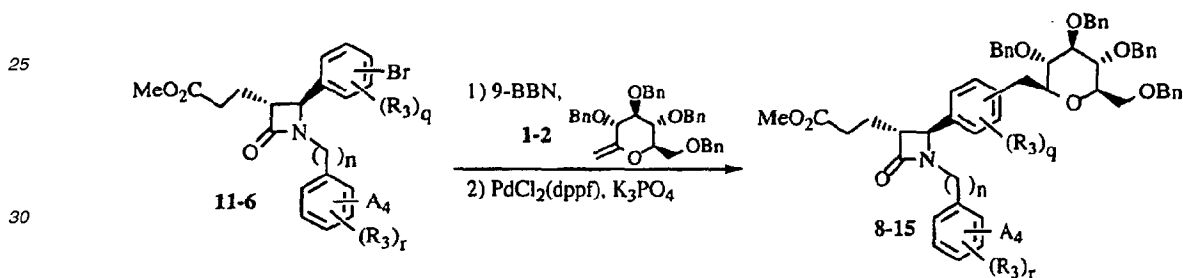
## Method 11

[0035] The preparative method of the optically active compounds (IV).

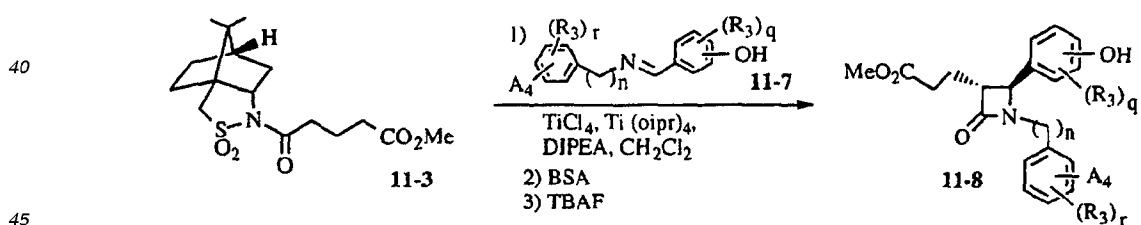
[0036] (R)-(+)-2,10-camphorsultam (11-1) is reacted with acid chloride (11-2) and obtained the compound (11-3). The compound (11-5) is obtained by coupling reaction of the compound (11-3) and the compound (11-4) in the presence of Lewis acids ( $\text{TiCl}_4$ ,  $\text{BF}_3 \cdot \text{OEt}_2$ ). The compound (11-5) is reacted with BSA, followed by reaction with TBAF (n-tetrabutylammonium fluoride) to afford the  $\beta$ -lactam compound (11-6).



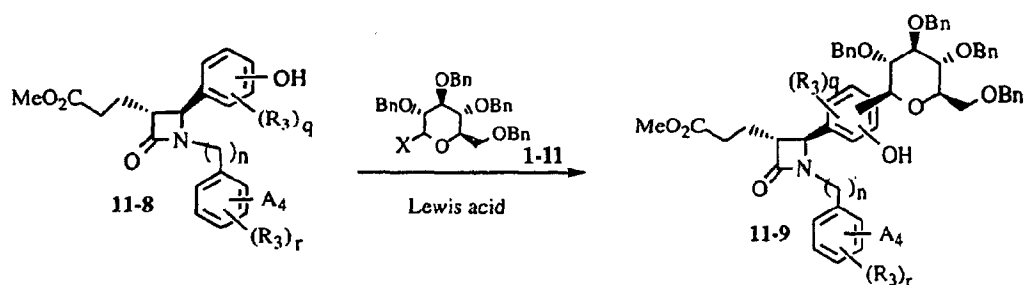
[0037] The obtained compound (11-6) is converted to the compound (8-15) by the same method as the method 8.



[0038] The compound (11-6) can be used as the starting material of the compound of general formula (I), according to the method 8. Furthermore, when the compound (11-7) is used instead of the compound (11-4), the compound (11-8) which correspond to the compound (11-6) can be obtained by the same method.



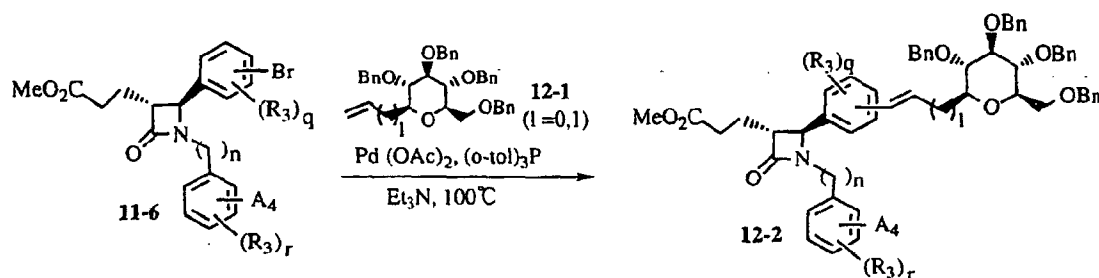
[0039] The compound (11-9) can be obtained from the compound (11-8) by the same method as the method 7.



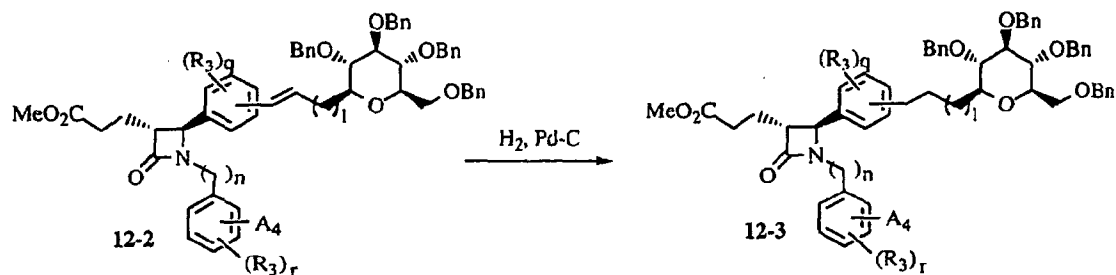
[0040] The compound (11-9) can be used as the starting material of general formula (I), according to the method 8.

#### Method 12

[0041] The compound (11-6) is subjected to Heck reaction with the compound (12-1) prepared by reported method (M. Yokoyama et al., *Synthesis* 1998, 409) and obtain the compound (12-2). (R. F. Heck et al., *J. Am. Chem. Soc.* 1968, **90**, 5518) The compound (12-2) can be used as the starting material of general formula (I), according to the method 8.



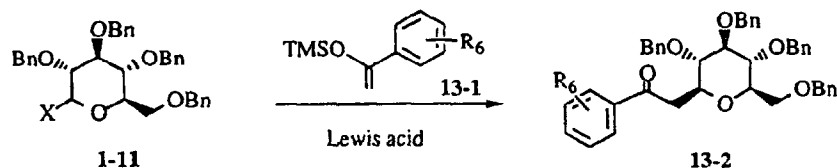
[0042] The compound (12-3) is obtained by hydrogenation of the compound (12-2). The compound (12-3) can be used as the starting material of general formula (I), according to the method 8.



#### Method 13

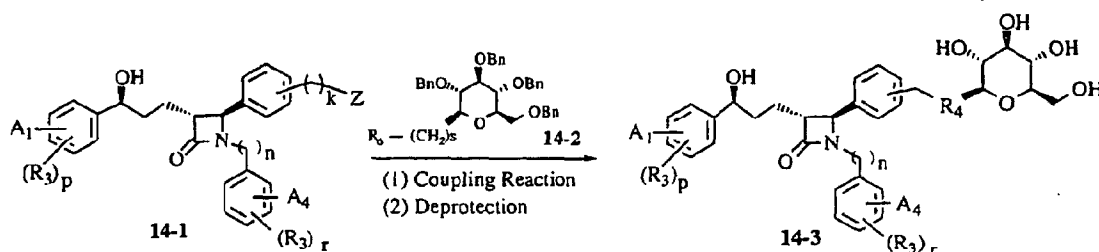
[0043] C-glycosidation of the compound (13-1) with the compound (1-11) ( $R_6$  is -Me, -Br, or -CH<sub>2</sub>OTBS) provides the compound (13-2) in the presence of Lewis acid (BF<sub>3</sub> OEt<sub>2</sub>, ZnCl<sub>2</sub>, AgOTf). (K. C. Nicolaou et al., *J. Chem. Soc., Chem. Comm.* 1984, 1153) The  $R_6$  of the compound (13-2) is converted to aldehyde by the same method as the method 1-(1)-(6), 1-(2), or 2-(2). The obtained compound can be used as the starting material of general formula (I), according to the method 1.





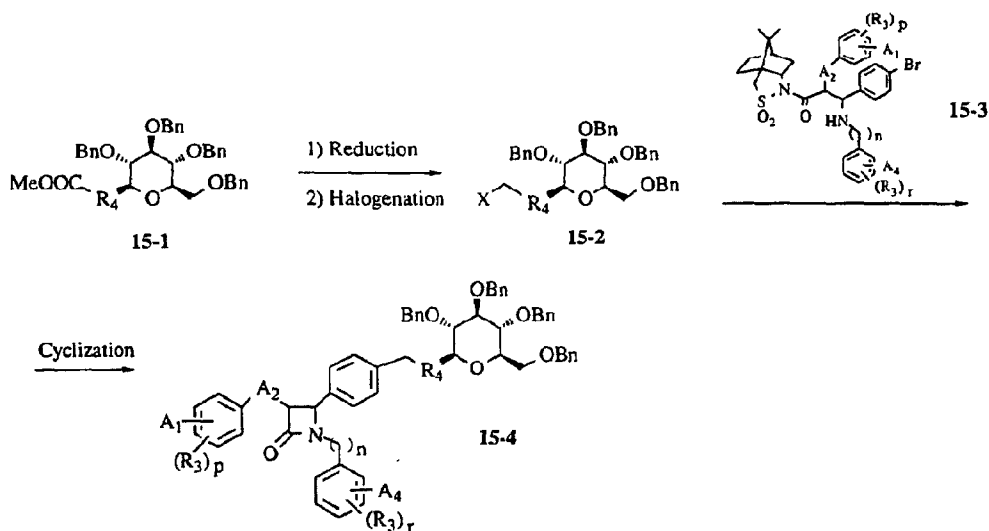
## Method 14

**[0044]** The compound (14-1) is subjected to the coupling reaction such as Suzuki coupling reaction and Grignard reaction (Angew. Chem. Int. Ed. Engl. 2000, 4415), or alkylation in the presence of base. After deprotection, the compound (14-3) is obtained.



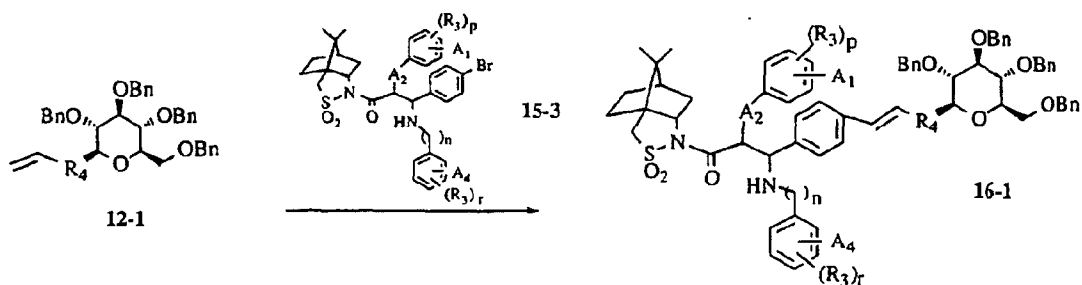
## Method 15

**[0045]** The compound (15-1) which is prepared by L. Dheilly's method (L. Dheilly et al., Carbohydr. Res. 1992, 224, 301), is converted to the compound (15-2) by reduction and halogenation. The compound (15-2) is transformed to the organometallic reagents (Grignard reagent, organozinc reagent), followed by coupling reaction with the compound (15-3) in the presence of palladium or nickel catalysts. Then, the compound (154) is obtained by cyclization.



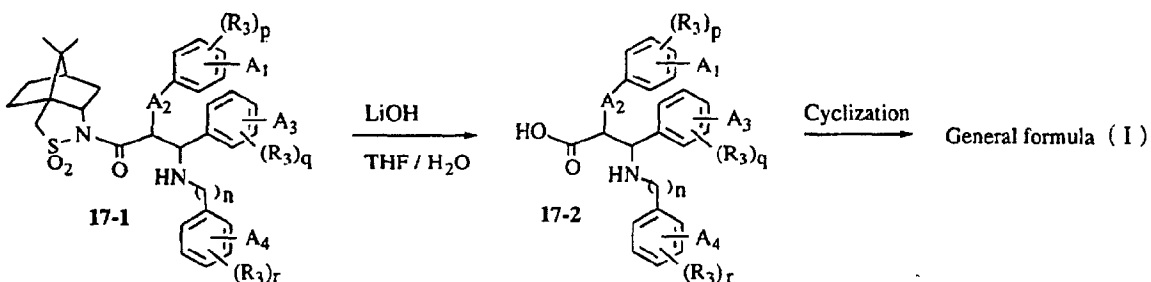
## Method 16

**[0046]** The compound (16-1) can be obtained by Heck reaction using the compound (12-1) and the compound (15-3) as same as the method 12. The compound (16-1) is converted to the general formula (I) according to the method 17.

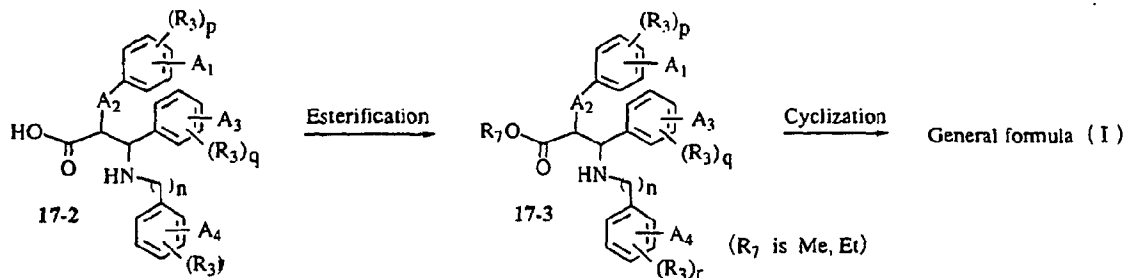


## Method 17

[0047] The compound (17-1) is treated with lithium hydroxide to remove camphorsultam and obtained the compound (17-2). (The camphorsultam can be collected and reused.) Then, the compound (17-2) is cyclized with  $\text{POCl}_3$  in the solvent such as dichloromethane or dichloroethane to yield the general formula (I). The compound of general formula (I) is also obtained by using the condensing reagents such as DCC (1,3-Dicyclohexycarbodiimide) or DEPC (Diethylphosphorylcyanide) in dichloromethane or DMF in the presence of base. Further the compound of general formula (I) is also obtained by using Mitsunobu reagent, DEAD (Diethylazodicarboxylate) or DIAD (Diisopropylazodicarboxylate) with  $\text{Bu}_3\text{P}$  or  $\text{Ph}_3\text{P}$  or by reacting with  $(\text{Py S})_2$  or after reacting with 2,6-dichloro-benzoyl chloride or 2,4,6-trichloro benzoyl chloride in the presence of  $\text{NaH}$  and treating with base like  $\text{NaOH}$  solution and obtained the general formula (I).

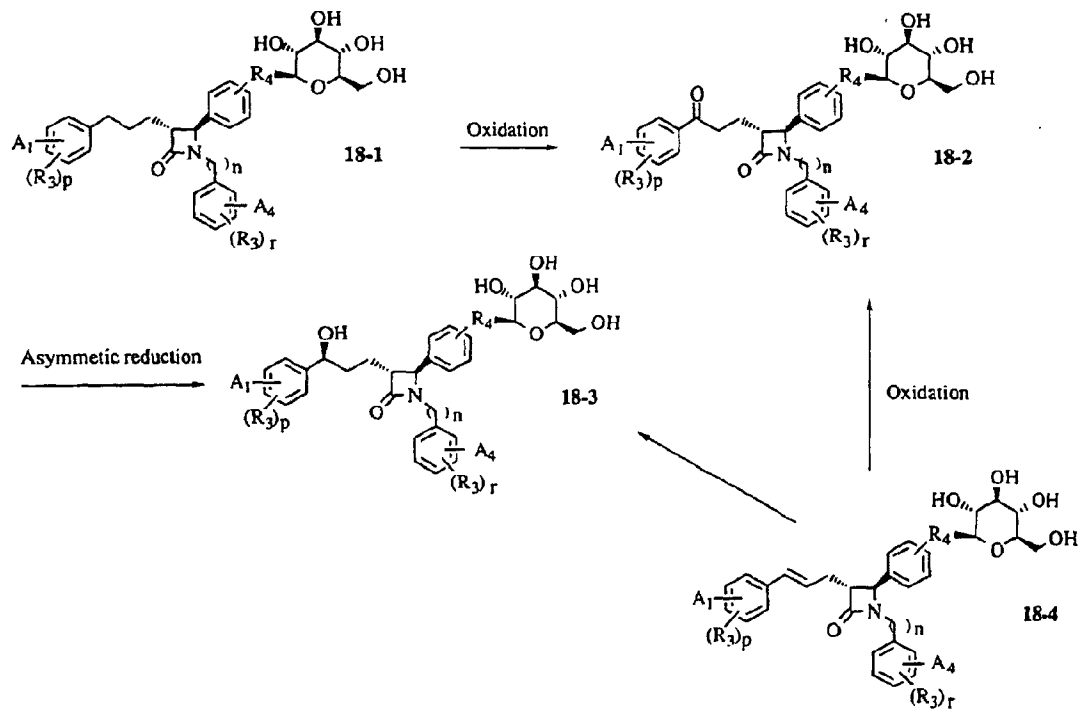


[0048] Or the compound (17-2) is esterified to the compound (17-3), followed by reaction of base such as  $\text{LDA}$ ,  $\text{LiHMDS}$  (lithium bis(trimethylsilyl)amide),  $\text{NaHMDS}$  (sodium bis(trimethylsilyl)amide),  $\text{NaH}$ ,  $t\text{-BuOK}$  in solvent such as THF to yield the general formula (I). The general formula (I) is also obtained by a reaction of Grignard reagent such as  $\text{EtMgBr}$ ,  $t\text{-BuMgBr}$  with compound (17-3). Applying the same reaction to the compound (17-1), the compound of the general formula (I) is obtained.



## Method 18

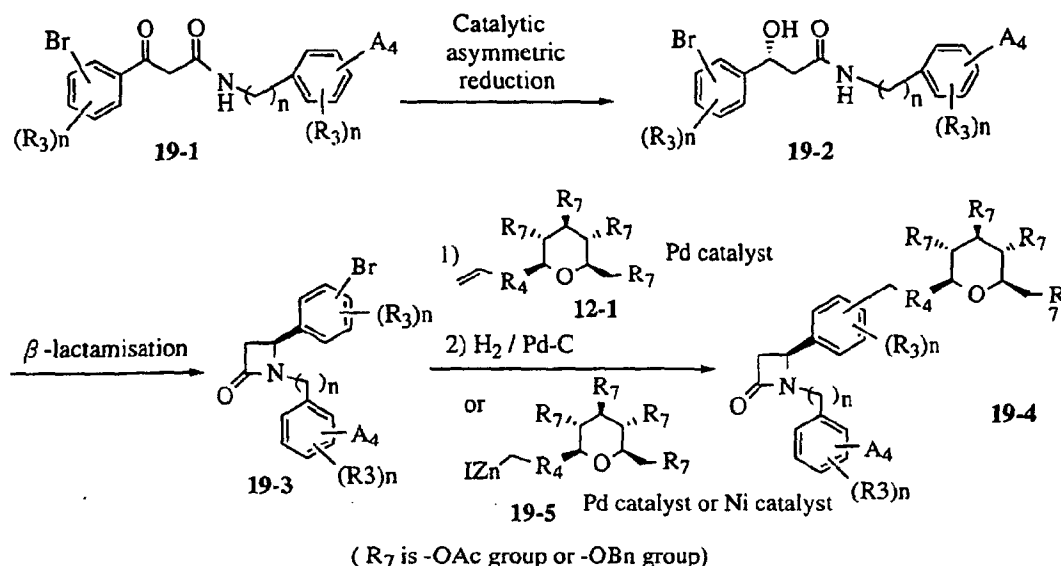
[0049] The compound (18-2) is obtained by  $\text{SeO}_2$  oxidation of the compound (18-4) or  $\text{Pd}(\text{OAc})_2$ -benzquinone- $\text{HClO}_4$  oxidation of the compound (18-4), then an asymmetric reduction of the ketone group of compound (18-2) provided to the compound (18-3). The compound (18-3) are also obtained by hydroboration of the compound (18-4). When a chiral borane reductant is used, the hydroboration proceeds stereoselectively.



[0050] In the formula which are described between method 1 and method 18,  $A_1$ ,  $A_2$ ,  $A_4$ ,  $R_3$ ,  $R_4$ ,  $p$ ,  $q$ ,  $r$ , and  $Z$  are as mentioned above, and  $R_6$  is  $-\text{CH}=\text{CH}_2$ ,  $-\text{CH}_2\text{OH}$ .  $k$  is integer of  $\geq 1$ ,  $l$  is 0 or an integer of  $\geq 1$ ,  $k+1$  is an integer of  $\leq 10$ .

Method 19

[0051]

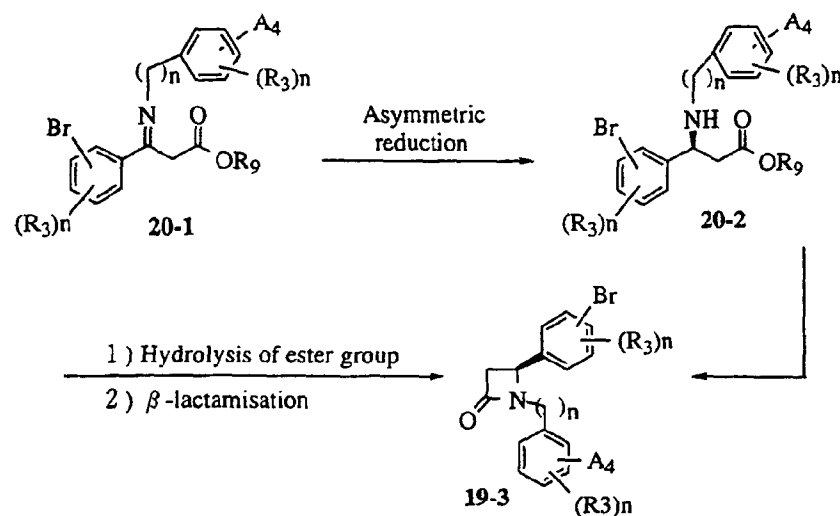


[0052] The compound (19-2) is obtained by asymmetric reduction of the compound (19-1). As asymmetric reductions, the transition metal catalysts are used (R.Noyori et al., J.Am.Chem.Soc. 1987, 109, 5856.). After the hydroxy group of the compound (19-2) is converted to a leaving group, the resulting compound is cyclized to obtain the compound (19-3). Or directly the compound (19-3) is obtained by Mitsunobu reaction of the compound (19-2). The compound (19-3) is subjected to Heck reaction with the compound (12-1), then the generated double bond is hydrogenated to give the compound (19-4). Or the compound (19-3) is subjected to Negishi coupling reaction (T.Hayashi et al., J.Am. Chem.Soc. 1984, 106, 158-163. ; A.Saiga et al., Tetrahedron Lett. 2000, 41, 4629-4632 ; C.Dai et al., J.Am.Chem.Soc., 2001, 123, 2719-2724) with the compound (19-5) to obtain the compound (19-4). The compound (19-4) can be used the synthetic material of the general formula (I) according to example 8.

## Method 20

## Synthesis of compound (19-3)

[0053]

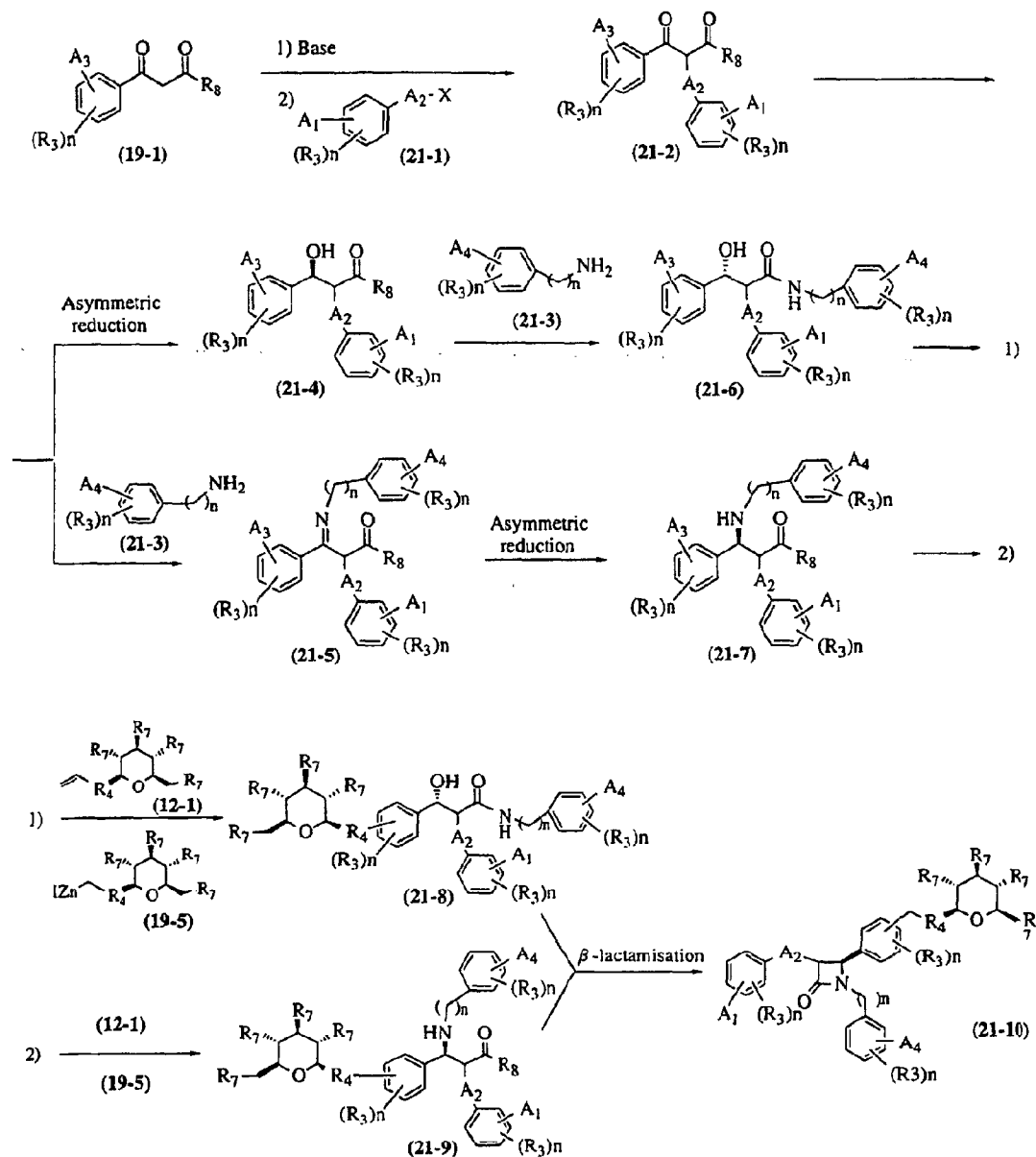


[0054] The imine compound (20-1) is subjected to asymmetric reduction to obtain the compound (20-2) according to example 19. The ester group of the compound (20-2) is hydrolyzed to the corresponding carboxylic acid compound and the obtained carboxylic acid is subject to β-lactamisation by using the condensing reagent (for example DCC) to give the compound (19-3). The compound (19-3) is also obtained by β-lactamisation of the compound (20-2) using EtMgBr for example. The compound (19-3) can be used the synthetic material of the general formula (I) according to example 19.

## Method 21

## Synthesis of compound (21-10)

[0055]



[0056] The compound (19-1) is reacted with an base, followed by addition of the compound (21-1) to give the compound (21-2). The compound (21-2) is converted to the compound (21-4) by asymmetric reduction or to the compound (21-5) by reaction with the compound (21-3).

[0057] The compound (21-4) is reacted with the compound (21-3) to afford the compound (21-6). Subsequently, the compound (21-6) is coupled with the sugar compound (12-1 or 19-5) to give the compound (21-8), then the  $\beta$ -lactam compound (21-10) is obtained.

[0058] On the other hand, after the compound (21-7) is obtained by asymmetric reduction of the compound (21-5) and the obtained compound (21-7) is coupled with the sugar compound (12-1 or 19-5) to afford the compound (21-9). The compound (21-10) is also obtained by  $\beta$ -lactamisation of the compound (21-9). The compound (21-10) can be the synthetic material of the general formula (I).

[ Hypocholesterolemic agents using the hypercholesterolemic hamster ]

**[0059]** Hamsters were derived into groups with 3 animals per group and fed a 0.5%-cholesterol containing CE-2 diet (CLEA Japan Inc.) for 4 or 7 days. The normal dietary group were fed a standard CE-2 during the experiment. Each compound or vehicle (0.2mL of corn oil) per 100g body weight was orally administered daily for 4 or 7 days from the day that high-cholesterol diet was started. At 20 hr after the final administration, blood samples were collected from the abdominal aorta of non-fasted animals under anesthesia with diethylether. Serum cholesterol was measured by enzymatic method using cholesterol E-test wako (Wako Pure Chemical Industries). Activity of the test compounds is expressed as percent reduction of the test compound on the basis of comparison with raised total cholesterol treated only with no-treatment-high-cholesterol diet. The test compounds with the optical rotation value in the compounds 1-58 were evaluated as the chiral compounds. The result is shown in the next table. Each value in the table shows the changed percent and the negative value indicates the positive hypocholesterolemic action.

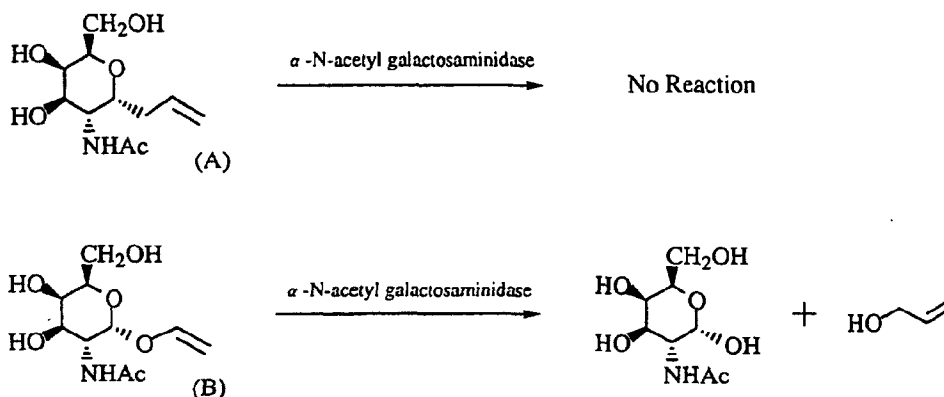
[Table 13]

No.	Test Comp. (mg/kg)	Dosage day	Serum cholesterol (%)
2	3	7	- 120
13	20	4	-28
15	20	4	-21
23	3	7	- 177
24	3	7	-156
28	3	7	- 130
33	3	4	- 67
38	10	4	- 2
45	3	4	-136
46	3	4	- 147
49	10	4	-55
56	0.3	4	- 84.0
57	0.3	4	-81.3

[Biological stability test]

**[0060]** To evaluate the stability of C-glycoside, the biological stability of C-allyl derivative (A) and O-allyl derivative (B) against to  $\alpha$ -N-acetyl-D-galactosaminidase as glycosidase were compared according to Mark von Itzstein's method (Org. Lett., 1999,1,443-446).

[Chemical formula 69]



enzyme :  $\alpha$ -N-acetyl galactosaminidase 0.32unit (1.69 unit/mL 0.1 % BSA containing 0.5M sodium citrate buffer)  
 solvent; citric acid buffer (pD=3) 0.6mL  
 temperature; 35°C  
 procedure; Substrate (2mg) was dissolved in citric acid buffer (0.6mL) and  $\alpha$ -N-acetyl galactosaminidase (0.32 unit) was added. NMR spectrum was determined in every constant time and the content of the remaining substrates were determined.

[0061] The result of the remaining substrates were shown in table 14.

[Table 14]

time substrate	2	4	6	8	10	12	18	24
B	89	79	68	57	50	45	40	22
A	100	100	100	100	100	100	100	100

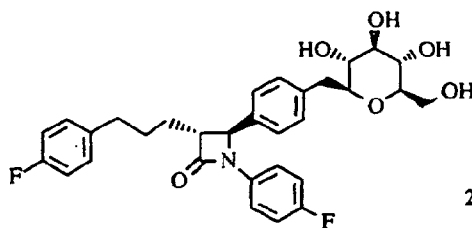
[0062] From the above results, 78% of O-allyl derivative (B) was clearly hydrolyzed after 24h. C-allyl derivative (A), replaced ether bond to C-C bond, was unaffected by enzyme as expected and the formation of the degradation was not observed after 24h.

#### [Example]

[0063] The following examples are provided only for the purpose of the preparation of the compound and not restrict the disclosed invention.

#### Reference 1

[0064] 4-(4-[(5S,2R,3R,4R,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)-perhydro-2H-pyran-2-yl]-methyl)phenyl)(4S\*,3S\*)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-on



#### Reference 1-a

#### Synthesis of compound (1-4)

[0065] A 50 mL of 9-BBN (0.5 M tetrahydrofuran solution) was added to a solution of the compound (1-2) (5.37g) in tetrahydrofuran (70 mL) and the mixture was refluxed for 5 hr, cooled to room temperature and 3 M potassium phosphate (10 mL) was added to the mixture at room temperature for 15 min. To the reaction mixture was added a solution of 4-(tert-butyldimethyl-silyloxymethyl)bromo-benzene (3.01 g) and PdCl<sub>2</sub> (dppf) (0.73 g) in N,N-dimethylformamide (100 mL). The mixture was stirred for 18 hr. The organic layer was washed with brine, dried over anhydrous sodium sulfate, and concentrated under reduced pressure. To the residue was added tetrabutylammonium fluoride (1.0 M tetrahydrofuran solution) (15 mL). The mixture was stirred for 3 hr and extracted with ethyl acetate. The organic layer was washed with brine, dried over anhydrous sodium sulfate, and concentrated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/2) to give 3.58 g (2 steps, 56%) of the compound (1-4).

Mass (ESI) m/z: 662 (M+H<sub>2</sub>O)<sup>+</sup>



IR (KBr) : 3430  $\text{cm}^{-1}$

$^1\text{H-NMR}$  ( $\text{CDCl}_3$ ) : 2.71(d, J=8.8, 13.2Hz), 3.13(d, J=2.4, 14.2Hz), 3.32~3.36(m, 2H), 3.45~3.50(m, 1H), 3.60~3.74(m, 4H), 4.48~4.68(m, 6H), 4.80~4.95(m, 4H), 7.18~7.37(m, 24H)

5 Reference 1-b

Synthesis of compound (1-5)

10 [0066] To a solution of the compound (1-4) (3.6 g) in chloroform (22.0 mL) was added manganese dioxide (9.65 g) and the mixture was refluxed for 2 hr, and cooled to room temperature. The mixture was filtered through a pad of Celite and evaporated to give 3.46 g (97%) of the compound (1-5) as a colorless crystal.

Mass (ESI) m/z: 660 ( $\text{M}+\text{H}_2\text{O}$ )<sup>+</sup>

IR (KBr) : 1692  $\text{cm}^{-1}$

15  $^1\text{H-NMR}$  ( $\text{CDCl}_3$ ): 2.77(d, J=8.8, 14.2Hz), 3.16~3.20(m, 1H), 3.32~3.36(m, 2H), 3.49(dt, J=2.0, 9.3Hz), 3.61~3.66(m, 3H), 3.72(t, J=8.8Hz), 4.46~4.67(m, 4H), 4.81~4.97(m, 4H), 7.18~7.41(m, 22H), 7.74(d, J=8.3Hz), 9.95(s, 1H)

Example 1

20 [0067]

(I) To a solution of the compound (1-5) (3.46 g) in toluene (54.0 mL) were added molecular sieve (3.46 g), a catalytic amount of p-toluenesulfonic acid and p-fluoroaniline (0.61 mL). The mixture was refluxed for 1.5 hr and filtered. The solvent was removed under reduced pressure and the residue was subjected to the next reaction without purification.

25 (II) To the solution of the compound obtained above in toluene (54.0 mL) were added tributylamine (5.1 mL) and 5-(4-fluorophenyl)pentanoyl chloride (1.16 g). After the mixture was refluxed for 15 hr and 1 N hydrochloric acid (15 mL) was added to the mixture and the mixture was stirred for 15 min. The organic layer was separated and washed with saturated sodium bicarbonate solution, brine and dried over anhydrous sodium sulfate and concentrated. The residue was subjected to the next reaction without purification.

30 (III) The solution of the compound obtained above in methanol-tetrahydrofuran (5/1) (6 mL) was hydrogenated at room temperature for 5 hr in the presence of 10% palladium on carbon (200 mg). After removal of the catalyst and the reaction mixture was evaporated and the residue was chromatographed on silica gel (chloroform/methanol= 10/1) to give 64 mg (26%) of the compound 2.

Mass (ESI) m/z : 554 ( $\text{M}+\text{H}$ )<sup>+</sup>

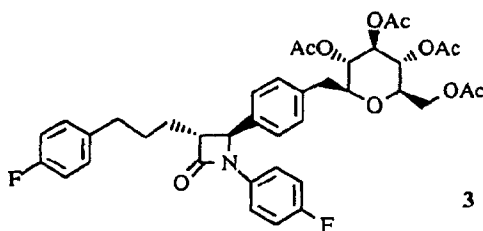
35 IR (KBr) : 3376, 1737, 1503, 1218  $\text{cm}^{-1}$

$^1\text{H-NMR}$  ( $\text{CD}_3\text{OD}$ ): 1.82~1.98(m, 4H), 2.65~2.78(m, 3H), 3.09~3.39(m, 7H), 3.64(d, J=5.4, 12.2Hz), 3.77~3.81(m, 1H), 4.94~4.98(m, 1H), 6.98~7.05(m, 4H), 7.18~7.22(m, 2H), 7.30~7.33(m, 4H), 7.38(d, J=7.8Hz, 2H)

40 Example 2

Synthesis of compound 3

45 [0068] 4-(4-[(5S,2R,3R,4R,6R)-3,4,5-triacetoxy-6-(acetoxymethyl)-perhydro-2H-pyran-2-yl)methyl]phenyl)-(4S\*, 3S\*)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]azetidine-2-one



55

[0069] To a solution of the compound 2 (600 mg) in dichloromethane (11.0 mL) were added triethylamine (0.77 mL), acetic anhydride (0.49 mL) and a catalytic amount of 4-dimethylamino-pyridine. The mixture was stirred at room temperature for 16 hr. The organic layer was washed with brine, dried over anhydrous sodium sulfate and concentrated.

The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/2) to give 600 mg (77%) of the compound 3.

Mass (ESI)  $m/z$  : 722 (M+H)<sup>+</sup>

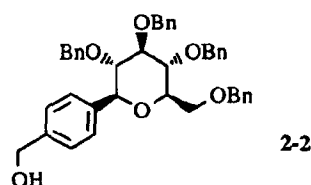
IR (KBr) : 1749,1506,1380,1221,1029  $\text{cm}^{-1}$

<sup>1</sup>H-NMR ( $\text{CDCl}_3$ ) : 1.82~1.84(m,4H), 1.93(s,3H), 1.97(s,1.5H), 1.98(s,1.5H), 1.99(s,1.5H), 2.00(s,1.5H), 2.02(s,3H), 2.61~2.64(m,2H), 2.79~2.82(m,2H), 3.07~3.08(m,1H), 3.56~3.69(m,2H), 4.02~4.23(m,2H), 4.58(d,  $J=2.4\text{Hz}$ ), 4.89~4.95(m,1H), 5.03(t,  $J=9.3\text{Hz}$ ), 5.17(t,  $J=9.3\text{Hz}$ ), 6.90~7.007(m,4H), 7.08~7.12(m,2H), 7.18~7.24(m,6H)

## Reference 2

Synthesis of compound (2-2) 4-(2,3,4,6-tetra-*o*-benzyl-  $\beta$ -D-glucopyranosyl)benzyl alcohol

### [0070]



[0071] To 7.31 g of tetrabenzylgluconolactone was added dropwise at -78 °C the lithium anion, prepared from 6.66 g of *p*-(*tert*-butyldiphenylsilyloxymethyl)bromobenzene and 10 mL of *n*-butyl lithium (1.57 M hexane solution) at -78 °C. The mixture was stirred for 2 hr and extracted with ethyl acetate. The organic layer was washed with brine, dried over anhydrous sodium sulfate and concentrated. The residue was subjected to the next reaction without purification. To a solution of the compound obtained above in dichloromethane (26 mL) were added triethylsilane (0.82 mL) and borontrifluoride-diethylether complex (0.33 mL) at -50 °C. The mixture was stirred for 1.5 hr. Sodium bicarbonate solution was added. The mixture was stirred for 1 hr, and then it was extracted with ether. The organic layer was washed with brine, dried over anhydrous sodium sulfate, and concentrated. The residue was purified by silica gel column chromatography to give 1.48 g (15%) of the compound (2-2).

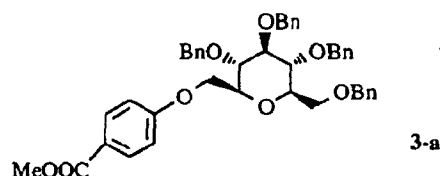
IR (KBr) : 3388,1452,1362,1210,1068,1026  $\text{cm}^{-1}$

<sup>1</sup>H-NMR ( $\text{CDCl}_3$ ) : 3.49~3.81(m,4H), 4.04~4.96(m,13H), 6.92~6.95(m,2H), 7.09~7.76(m, 2H)

## Reference 3-a

4-(2,3,4,6-tetra-*o*-benzyl-  $\beta$ -D-glucopyranosyl)methoxy benzoic acid methyl ester

### [0072]



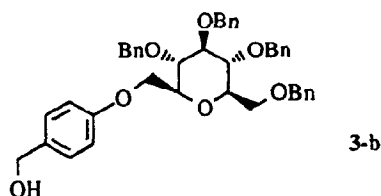
[0073] To a solution of the compound (3-1) (555 mg), methyl *p*-hydroxy benzoate (153 mg) and triphenylphosphine (394 mg) in tetrahydrofuran (5.0 mL) was added diisopropylazodicarboxylate (0.3 mL). The mixture was stirred for 22 hr and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/3) to give 180 mg (26%) of the compound (3-a).

IR (neat) : 1713,1605,1434,1359,1248,1164  $\text{cm}^{-1}$

<sup>1</sup>H-NMR ( $\text{CDCl}_3$ ) : 3.49~3.77(m,7H), 3.89(s,3H), 4.07~4.11(m,1H), 4.19~4.22(m,1H), 4.51~4.60(m,4H), 4.82~4.89(m,2H), 4.94(s,2H), 6.87(d,  $J=8.8\text{Hz}$ , 2H), 7.15~7.36(m,20H), 7.96(d,  $J=8.8\text{Hz}$ , 2H)

4-(2,3,4,6-tetra-*o*-benzyl-  $\beta$ -D-glucopyranosyl)methoxy benzyl alcohol

**[0074]**



**[0075]** To a suspension of 10 mg of lithium aluminiumhydride in 5 mL of ether was added 180 mg of the compound (3-a) in 5 mL of ether at 0 °C. After the mixture was stirred at room temperature for 15 min, water (2.0 mL) and 15% sodium hydroxide solution (0.5 mL) were added and the resulting suspension was filtered through a pad of Celite. After removal of the solvent, the residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/1) to give 160 mg (93%) of the compound (3-b).

Mass (ESI)  $m/z$ : 684 ( $M+H+Na$ )<sup>+</sup>

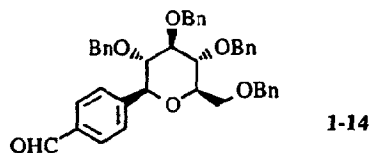
IR (neat) : 3442  $\text{cm}^{-1}$

<sup>1</sup>H-NMR (CDCl<sub>3</sub>) : 1.56(s,1H), 3.49~3.53(m,1H), 3.60~3.77(m,6H), 4.08~4.12(m,1H), 4.20 ~4.23(m,1H), 4.52~4.61(m,6H), 4.85(ABq,J=11.2Hz,2H), 4.93(s,2H), 6.88(d,J=8.8Hz 2H), 7.15~7.36(m,22H)

Reference 3-c

#### Synthesis of compound (1-14) 4-(2,3,4,6-tetra-*o*-benzyl- $\beta$ -D-glucopyranosyl)benzaldehyde

[0076]



(l) To a solution of the 4-(2,3,4,6-tetra-*o*-benzyl-  $\beta$ -D-glucopyranosyl)toluene (0.3 g) in carbon tetrachloride (3 mL) were added NBS (0.9 mg) and benzoylperoxide (0.05 g). The mixture was refluxed for 2 hr. After cooling to room temperature, ether (30 mL) was added to the mixture. The resulting salts were filtered off by suction. The filtrate was concentrated and the residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/8).

(II) To a solution of bromide (224 mg) obtained above in dimethylsulfoxide (3 mL) was added sodium bicarbonate (45 mg). After the mixture was stirred at room temperature for 1 hr and 100 °C for 4 hr, the mixture was extracted with ethyl acetate (30 mL). The organic layer was washed with brine, and dried over anhydrous sodium sulfate. Removal of the solvent under reduced pressure gave the compound (1-14) (2 steps 26%).

Mass (m/z) : 436 (M<sup>+</sup>), 394,307,273,245,214,163,135,105,77,51(BP)

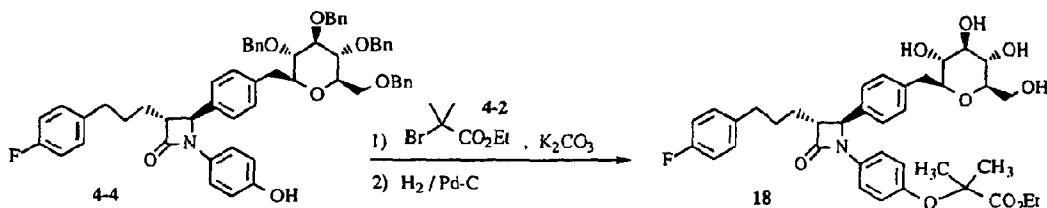
IR (neat) : 2914,1641,1437,1257,1017,954,708 cm<sup>-1</sup>

<sup>1</sup>H-NMR(CDCl<sub>3</sub>, 400MHz) δ: : 1.96, 1.97, 2.06(12H, each, s), 3.75~5.40(7H, m), 7.96, 8.02(4H, ABq), 10.06(1H, s)

## Example 3

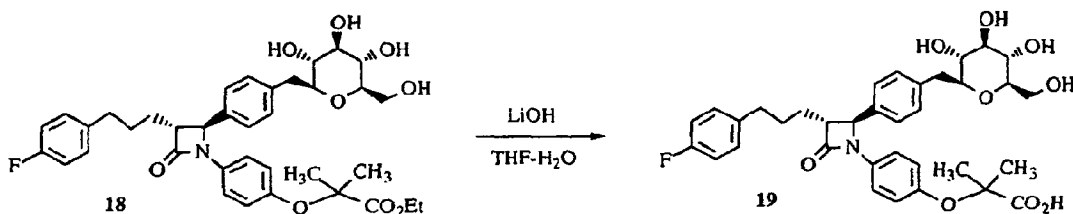
2-(4-[4-((5S,2R,3R,4R,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)-perhydro-2H-pyran-2-yl)methyl]phenyl)(4S\*,3R\*)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]-2-oxazetidineyl) phenoxy-2-methylpropanoic acid

[0077]



(I) To a solution of the compound (4-4) (3.19 g) in acetone (22.0 mL) were added ethyl 2-bromo-2-methylpropanoate (0.77 mL) and potassium carbonate (0.97 g). The mixture was refluxed for 40 hr, filtered, and concentrated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/3).

(II) A solution of the compound 18 (2.93 g) obtained above in ethanol-tetrahydrofuran (1/1) (40 mL) was hydrogenated at room temperature for 3 hr in the presence of 10% palladium on carbon (0.3 g). After removal of the catalyst, the filtrate was evaporated. The residue was purified by silica gel column chromatography (chloroform/methanol = 10/1) to give 1.21 g (2 steps 51.8%) of the compound 18.



[0078] To a solution of the compound 18 (400 mg) in tetrahydrofuran-water (5/1) (3 mL) was added lithium hydroxide (50 mg). The mixture was stirred at room temperature for 8 hr and 1 N hydrochloric acid was added to adjust to pH 3. The mixture was extracted with ethyl acetate. The organic layer was washed with brine, dried over anhydrous sodium sulfate and concentrated. The residue was purified by silica gel column chromatography (chloroform/methanol = 5/1) to give 377 mg (3 steps 51.0%) of the compound 19.

Mass (ESI)  $m/z$ : 636 (M-H)<sup>-</sup>

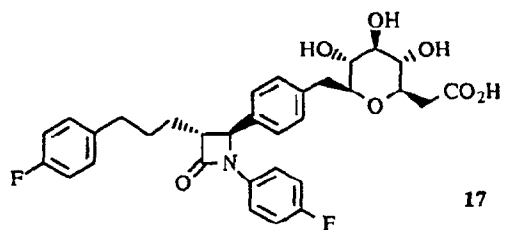
IR (KBr): 3400, 1722, 1503  $\text{cm}^{-1}$

<sup>1</sup>H-NMR(CD<sub>3</sub>OD): 1.53(s, 6H), 1.81~1.95(m, 4H), 2.65~2.68(m, 2H), 2.72~2.78(m, 1H), 3.09~3.41(m, 7H), 3.62~3.66(m, 1H), 3.77~3.82(m, 1H), 4.81(d,  $J=2.0\text{ Hz}$ , 1H), 6.85(d,  $J=9.3\text{ Hz}$ , 2H), 6.97~7.02(m, 2H), 7.18~7.22(m, 4H), 7.30(d,  $J=7.8\text{ Hz}$ , 1H), 7.38(d,  $J=8.3\text{ Hz}$ , 2H)

## Example 4

Synthesis of compound 17

[0079] 6-[(4-((2S\*,3S\*)1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]-4-oxazetidine-2-yl)(2S,3S,4R,5R,6R)-3,4,5-trihydroxyperhydro-2H-pyran-2-carboxylic acid



**[0080]** To a mixture of the compound 2 (300 mg), 2,2,6,6-tetramethyl-1-piperodinyloxy, free radical (10 mg) and potassium bromide (10 mg) in acetonitrile (6.6 mL) were added saturated sodium bicarbonate solution (6.6 mL) and sodium hypochlorite (6.6 mL). The mixture was stirred at room temperature for 3 hr and then extracted with ethyl acetate. The organic layer was washed with brine, dried over anhydrous sodium sulfate and concentrated. The residue was purified by silica gel column chromatography (chloroform/methanol = 10/1) to give 90 mg (29.4%) of the compound 17.

Mass (ESI)  $m/z$ : 566 (M-H)<sup>-</sup>

IR (KBr) : 3388, 1737, 1509  $\text{cm}^{-1}$

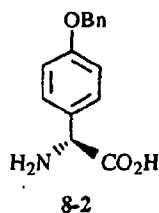
<sup>1</sup>H-NMR (CD<sub>3</sub>OD) : 1.82~1.97(m, 4H), 2.65~2.68(m, 2H), 2.71~2.79(m, 1H), 3.12~3.24(m, 3H), 3.34~3.52(m, 3H), 3.62~3.68(m, 1H), 4.84(d,  $J=2.0\text{Hz}$ , 1H), 6.98~7.05(m, 4H), 7.18~7.21(m, 2H), 7.29~7.37(m, 6H)

Reference 4-a

Synthesis of compound (8-2)

D-p-Benzoyloxyphenylglycine

**[0081]**



**[0082]** To a solution of D-p-hydroxyphenylglycine (16.7 g) in 2 N sodium hydroxide (50 mL) was added a solution of copper sulfate (12.5 g) in water (100 mL). The mixture was stirred at 60 °C for 1 hr. After cooling to room temperature, 2 N sodium hydroxide (50 mL), methanol (50 mL) benzyl bromide (13.0 mL) were added. The mixture was stirred at room temperature for 20 hr. Resulting salts were collected by suction, washed with water and acetone and the residue dissolved in 1 N hydrochloric acid (300 mL) and the mixture was stirred at room temperature for 1 hr. Resulting salts were collected by suction, washed with water and acetone and dried to give 13.18 g (51.3%) of the compound (8-2).

Mass  $m/z$ : 212 (M-45)<sup>+</sup>, 122, 91 (base), 65

IR (KBr) : 3022, 1587, 1509, 1389, 1248, 1008  $\text{cm}^{-1}$

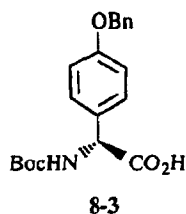
<sup>1</sup>H-NMR (CD<sub>3</sub>OD) : 5.07(s, 1H), 5.16(s, 2H), 7.12(d,  $J=6.8\text{Hz}$ , 2H), 7.34~7.48(m, 5H), 7.45(d,  $J=6.8\text{Hz}$ , 2H)

Reference 4-b

Synthesis of compound (8-3)

D-p-Benzyloxyphenyl-N-(tert-butoxycarbonyl)glycine

[0083]



[0084] To a solution of the compound (8-2) (12.53 g) in tetrahydrofuran-water (140 mL) were added triethylamine (16.4 mL) and di-tert-butyl-Bicarbonate (13.5 mL) at 0 °C. After the mixture was stirred at room temperature for 4 hr, the mixture was concentrated under reduced pressure. The residue was added with 10% citric acid solution to pH 4 and extracted with ethyl acetate (100 mL×3). The organic layer was washed with water (100 mL×3), brine (100 mL) and dried (Na<sub>2</sub>SO<sub>4</sub>). After removal of the organic solvent under reduced pressure, 17.4 g (quantitative) of the compound (8-3) was obtained.

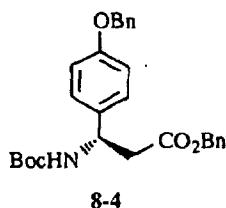
Mass m/z : 357 (M<sup>+</sup>), 331,301,283,256,212,148,120,91(base)IR(KBr): 3298,2968,1791,1656,1608,1506,1452,1392,1242,1161 cm<sup>-1</sup><sup>1</sup>H-NMR (CDCl<sub>3</sub>) : 1.23(s,9H), 5.05(bs,3H), 6.94(d,J=8.3Hz,2H), 7.32~7.41(m,8H)

Reference 4-c

Synthesis of compound (8-4)

Benzyl (3S)-3-[4-(benzyloxy)phenyl]-3-[(tert-butoxy)carbonylamino]propionate

[0085]



[0086] To a solution of the compound (8-3) (14.4 g) in tetrahydrofuran (80 mL) were added triethylamine (5.9 mL) and isobutylchloroformate (5.8 mL) at 0 °C. After the mixture was stirred for 40 min, ether solution of diazomethane, prepared from N,N-dimethylnitrosourea (30.0 g) and 40% potassium hydroxide solution (100 mL), was added. The mixture was stirred for 1.5 hr and then quenched with acetic acid. Ether (100 mL) and water (100 mL) were added to the mixture. The separated organic layer was washed with satd.Na<sub>2</sub>CO<sub>3</sub> solution (100 mL×2), brine (100 mL), dried (Na<sub>2</sub>SO<sub>4</sub>) and evaporated. To a solution of the residue in tetrahydrofuran (80 mL)-water (15 mL) was added a solution of silver benzoate (0.93 g) in triethylamine (8.3 mL). After the mixture was stirred at room temperature for 2 hr, the mixture was diluted with ether (100 mL). The ether solution was washed with 10% hydrochloric acid (50 mL×2), water (100 mL×4), brine (50 mL), dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated. To a solution of the residue in acetonitrile (80 mL) were added DBU(7.0 mL) and benzylbromide (5.7 mL). The mixture was stirred at room temperature for 4 hr and diluted with ethyl acetate. The ethyl acetate extract was washed successively with 10% citric acid solution (50 mL×2), satd. Na<sub>2</sub>CO<sub>3</sub> (100 mL), brine (100 mL), dried (Na<sub>2</sub>SO<sub>4</sub>) and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/2) to give 10.35 g (55.7%) of the compound (8-4).

Mass m/z : 461 (M<sup>+</sup>), 404,360,314,270,212,180,121,91,57(base)

IR (KBr) : 3394,2956,1731,1689,1500,1290,1224,1149  $\text{cm}^{-1}$

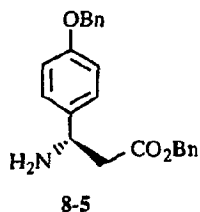
$^1\text{H-NMR}(\text{CDCl}_3)$  : 1.51(s,9H), 2.89~3.12(m,2H), 5.10(s,4H), 5.09~5.13(m,1H), 6.99(d,  $J=8.8\text{Hz}$ ,2H), 7.30~7.54(m,12H)

5 Reference 4-d

Synthesis of compound (8-5)

[0087]

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20 Benzyl (3S)-3-amino-4-(benzyloxy)phenylpropionate hydrochloride

[0088] To a solution of the compound (8-4) (3.00 g) in ethyl acetate (30 mL) was added 17% hydrochloric acid in ethanol (10 mL). The mixture was stirred for 3 hr and concentrated under reduced pressure. To the residue was added ethyl acetate-hexane (1/4) in order to crystallize. The resulting crystals were filtered and dried to give 2.46 g (95.2%) of the compound (8-5).

25 Mass  $m/z$  361 ( $M-36.5$ )<sup>+</sup>, 344, 270, 147, 121, 91 (base), 65

IR (KBr) : 3016, 2908, 1725, 1581, 1512, 1299, 1245, 1185  $\text{cm}^{-1}$

$^1\text{H-NMR}(\text{CDCl}_3)$  : 3.05(d,  $J=6.4\text{Hz}$ , 18.3Hz, 1H), 3.27(d,  $J=6.4\text{Hz}$ , 16.8Hz, 1H), 4.64~4.65(m, 1H), 4.94~5.03(m, 4H), 6.89(d,  $J=8.7\text{Hz}$ , 2H), 7.15~7.41(m, 12H), 8.77~8.78(m, 3H)

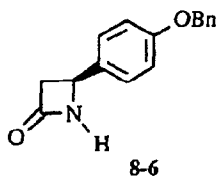
30 Reference 4-e

Synthesis of compound (8-6)

(4S)-4-[4-(benzyloxy)phenyl]azetidine-2-one

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[0089]



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[0090] To a suspension of the compound (8-5) (6.48 g) in ethyl acetate were added water (15 mL) and 1 M potassium carbonate solution to make alkaline. The mixture was extracted with ethyl acetate (30 mL×2). The organic layer was washed with brine (50 mL), dried ( $\text{Na}_2\text{SO}_4$ ) and evaporated. To a solution of the residue in benzene (60 mL) were added triethylamine (3.6 mL) and chlorotrimethylsilane (2.7 mL). The mixture was stirred at room temperature for 14 hr and filtered through a pad of Celite. The filtrate was evaporated under reduced pressure and the residue was dissolved in ether (65 mL) and a solution of 2 M tert-butylmagnesium chloride in ether (10.7 mL) was added at 0 °C and stirred at room temperature for 18 hr and then saturated ammonium chloride solution (50 mL), ethyl acetate (50 mL) and 10% hydrochloric acid (50 mL) were added successively at 0 °C. After the resulting mixture was stirred at room temperature for 1 hr, the water layer was extracted with ethyl acetate. The combined ethyl acetate extracts were washed with water (50 mL), satd.  $\text{NaHCO}_3$  (50 mL), and brine (50 mL), dried ( $\text{Na}_2\text{SO}_4$ ) and evaporated. The residue was purified by silica gel column chromatography (chloroform/acetone = 10/1) to give the objective compound as a crude solid. This solid was purified by washing with ethyl acetate-hexane to give 2.50 g (60.7%) of the compound (8-6).

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Mass  $m/z$  : 253 ( $M^+$ ), 162, 91 (base), 65

IR (KBr) : 3184,1749,1698,1540,1410,1248,1100  $\text{cm}^{-1}$

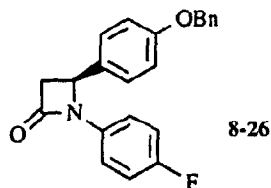
$^1\text{H-NMR}(\text{CDCl}_3)$  : 2.84~2.88(d,J=1.0Hz,2.4Hz,15.1Hz,1H), 3.39~3.44(d,J=2.4Hz, 5.4Hz, 14.8Hz,1H), 4.68(d,J=4.9Hz,14.9Hz,1H), 5.08(s,2H), 6.09(bs,1H), 6.97(d,J=2.9Hz,7.8Hz,2H), 7.287~44(m,7H)

5 Reference 4-f

Synthesis of (4S)-4-[4-(benzyloxy)phenyl]-1-(4-fluorophenyl)azetidine-2-one

[0091]

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[0092] To a solution of the compound (8-6) (1.00g) in dichloromethane (10 mL) were added triethylamine (0.8 mL), 4-fluorophenylboronic acid (1.11 g) and copper acetate (0.75 g). The mixture was refluxed for 48 hr and evaporated under reduced pressure. The residue was partitioned in ethyl acetate (50 mL) and water (50 mL). The water layer was extracted with ethyl acetate (50 mL  $\times$  3). The combined ethyl acetate extracts were washed successively with water (50 mL), 10% hydrochloric acid (50 mL), saturated sodium bicarbonate solution (50 mL), and brine (50 mL), dried over anhydrous sodium sulfate and concentrated. The residue was purified by silica gel column chromatography (benzene/ether = 12/1) to give a solid, which was recrystallized from ethyl acetate-hexane to give 1.06 g (77.3%) of the objective compound (8-26).

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Mass  $m/z$ : 347 ( $\text{M}^+$ ), 256,210,137,91(base), 65

IR (KBr) : 1731,1620,1506,1380,1242  $\text{cm}^{-1}$

$^1\text{H-NMR}(\text{CDCl}_3)$  : 2.93(d,J=3.0Hz,15.2Hz,1H), 3.52(d,J=5.4Hz,15.2Hz,1H), 4.93(d,J=2.4Hz, 5.4Hz,1H), 5.05(s,2H), 6.90~6.99(m,4H), 7.24~7.43(m,9H)

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Reference 4-g

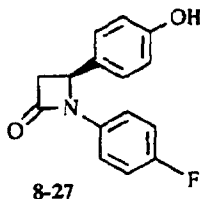
Synthesis of compound (8-27)

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(4S)-1-(4-fluorophenyl)-4-(hydroxyphenyl)azetidine-2-one

[0093]

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[0094] A solution of the compound 8-26 (2.00 g) obtained above step reference 4-f in ethyl acetate-methanol (50 mL) was hydrogenated at room temperature for 9 hr in the presence of 5% palladium on carbon (0.20 g). After removal of the catalyst through a pad of Celite, the solvent was evaporated and the residue was purified by silica gel column chromatography (chloroform/acetone = 10/1) to give 1.36 g (91.9%) of the compound (8-27).

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Mass  $m/z$  : 257 ( $\text{M}^+$ ), 214,120(base), 91, 58

IR (KBr) : 3106,1707,1620,1503,1453,1383,1257,1218  $\text{cm}^{-1}$

$^1\text{H-NMR}(\text{CDCl}_3)$ : 2.93(d,J=2.4Hz,15.7Hz,1H), 3.53(d,J=5.9Hz,15.2Hz,1H), 4.94(d,J=2.9Hz, 5.4Hz,1H), 5.22(s,1H), 6.85(d,J=8.3Hz,2H), 6.93(s,J=8.8Hz,2H), 7.23~7.27(m,4H)

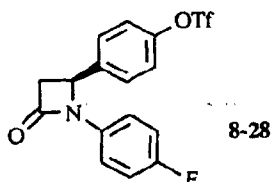
55



Reference 4-h

Synthesis of 4-[(2S)-1-(4-fluorophenyl)-4-oxoazetidine-2-yl]phenyl]trifluoromethanesulfonate

[0095]



[0096] To a suspension of the compound (8-27) (0.35 g) in dichloromethane (10 mL) were added pyridine (0.12 mL) and trifluoromethanesulfonic anhydride (0.26 mL) at 0 °C. The mixture was stirred for 1 hr and poured into ice-cold water (20 mL). The resulting mixture was extracted with ethyl acetate (30 mL×2). The combined ethyl acetate extracts were washed with 10% hydrochloric acid (20 mL), saturated sodium bicarbonate solution (40 mL), brine (30 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/3) to give 0.48 g (90.7%) of the objective compound (8-28).

Mass  $m/z$  : 389 ( $M^+$ ), 347, 252, 214, 186, 137, 119 (base), 69

IR (KBr): 1734, 1509, 1416, 1383, 1248, 1212, 1131, 900  $\text{cm}^{-1}$

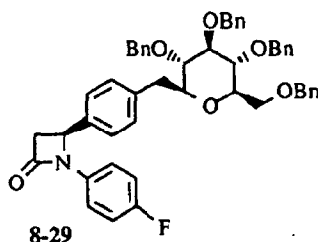
$^1\text{H-NMR}$  ( $\text{CDCl}_3$ ) : 2.94 (d,  $J=2.5\text{Hz}$ , 15.2Hz, 1H), 3.16 (d,  $J=5.9\text{Hz}$ , 15.2Hz, 1H), 5.04 (d,  $J=2.5\text{Hz}$ , 5.4Hz, 1H), 6.98 (t,  $J=8.8\text{Hz}$ , 2H), 7.21~7.25 (m, 2H), 7.31 (d,  $J=2.0\text{Hz}$ , 6.8Hz, 2H), 7.45 (d,  $J=2.2\text{Hz}$ , 6.8Hz, 2H)

Reference 4-i

Synthesis of compound (8-29)

(4S)-4-[4-[(2S,5S, 3R, 4R, 6R)-6-[(benzyloxy)methyl]-3,4, 5-tribenzyloxy]perhydro-2H-pyran-2-yl]methyl]phenyl]-1-(4-fluorophenyl)azetidine-2-one

[0097]



[0098] To a solution of the compound (8-28) (0.32 g) in tetrahydrofuran (4.1 mL) was added 0.5 M9-BBN in tetrahydrofuran (3 mL) and the mixture was refluxed for 6 hr. After cooling to room temperature, 3 M potassium phosphate solution (0.6 mL), tetrahydrofuran (4.7 mL), the compound obtained in reference 4-h (0.22 g) and  $\text{PdCl}_2(\text{dppf})$  (0.042 g) were added to the mixture and the resulting mixture was stirred at 50 °C for 16 hr. To the mixture were added water (30 mL) and ethyl acetate (30 mL) and the resulting mixture was filtered through a pad of Celite. The filtrate was extracted with ethyl acetate (30 mL×2). The combined ethyl acetate extracts were washed with water (30 mL×2) and brine (30 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/4) to give 0.209 g (45.4%) of the compound (8-29).

Mass (ESI)  $m/z$ : 800 ( $M+\text{Na}(23))^+$

IR (KBr) : 2896, 1746, 1509, 1377, 1095, 1068, 750  $\text{cm}^{-1}$

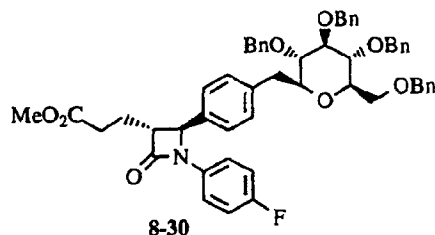
$^1\text{H-NMR}$  ( $\text{CDCl}_3$ ) : 2.69~2.75 (d,  $J=7.8\text{Hz}$ , 14.7Hz, 1H), 2.89 (d,  $J=2.5\text{Hz}$ , 15.1Hz, 1H), 3.12 (d,  $J=1.5\text{Hz}$ , 14.2Hz, 1H), 3.30~3.37 (m, 2H), 3.46~3.53 (m, 2H), 3.59~3.74 (m, 8H), 4.45~4.64 (m, 4H), 4.81~4.94 (m, 5H), 6.90 (t,  $J=8.8\text{Hz}$ , 2H), 7.19~7.35 (m, 26H)

Reference 4-j

Synthesis of compound (8-30)

5 Methyl 3-[(4S,3R)-4-[4-[(2S,5S,3R,4R,6R)-6-(benzyloxymethyl)-3,4,5-tribenzyloxy]perhydro-2H-pyran-2-yl]methyl]phenyl]-1-(4-fluorophenyl)oxazetidine-3-yl]propionate

[0099]



[0100] To a solution of 2 M lithium diisopropylamide (1.3 mL) in tetrahydrofuran (3 mL) was added a solution of the compound (8-29) (1.00 g) in tetrahydrofuran (1.5 mL) at -78 °C and the mixture was stirred for 1 hr and a solution of methyl acrylate (0.132 g) in tetrahydrofuran (2 mL) was added to the mixture. The resulting mixture was stirred for 0.5 hr and the mixture was quenched with saturated ammonium chloride solution (30 mL) and extracted with ethyl acetate (60 mL × 2). The combined ethyl acetate extracts were washed with water (50 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/4) to give 0.793 g (71.8%) of the compound (8-30).

Mass (ESI)  $m/z$  : 864 ( $M+1$ )<sup>+</sup>IR (KBr) : 2854, 1740, 1509, 1452, 1362, 1215, 1140, 1098  $\text{cm}^{-1}$ 

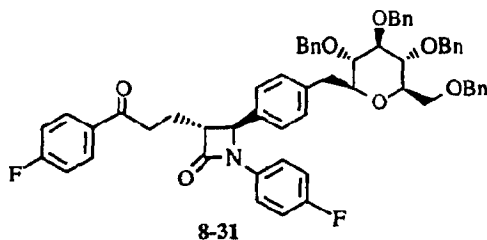
<sup>1</sup>H-NMR ( $\text{CDCl}_3$ ) : 2.19~2.23(m, 2H), 2.47~2.59(m, 2H), 2.72(d,  $J=8.8\text{Hz}$ , 14.6Hz, 1H), 3.04~3.13(m, 2H), 3.30~3.37(m, 2H), 3.42~3.48(m, 1H), 3.64(s, 3H), 3.61~3.74(m, 4H), 4.47~4.63(m, 5H), 4.81~4.94(m, 4H), 6.90(t,  $J=8.8\text{Hz}$ , 2H), 7.15~7.35(m, 26H)

Reference 4-k

Synthesis of compound (8-31)

(4S,3R)-4-[4-[(2S,5S,3R,4R,6R)-6-(benzyloxy)methyl]-3,4,5-tribenzyloxy]perhydro-2H-pyran-2-yl]methyl]phenyl]-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)-3-oxopropyl]azetidine-2-one

[0101]



[0102] To a solution of the compound (8-30) (1.75 g) in tetrahydrofuran-methanol (20 mL) were added water (5 mL) and lithium hydroxide (0.084 g). The mixture was stirred at room temperature for 4 hr. The reaction mixture was acidified by addition of 10% hydrochloric acid and extracted with ethyl acetate (30 mL × 3). The combined ethyl acetate extracts were concentrated under reduced pressure, and the residue was passed through a short silica gel column (ethyl acetate/hexane = 1/1) to give the crude product which was subjected to the next reaction without further purification. To a solution of the compound obtained above in dichloromethane (8.4 mL) was added 2 M oxalyl chloride (0.84 mL) in dichloromethane and the mixture was stirred at room temperature for 16 hr. Removal of the organic solvent gave the crude acid chloride. To a suspension of zinc chloride (0.368 g) in tetrahydrofuran (8 mL) was added 4-fluorophenyl-

magnesium bromide, prepared from magnesium (0.084 g) and 4-bromofluorobenzene (0.47 g) in tetrahydrofuran (8 mL). The mixture was stirred at room temperature for 1 hr and tetrakis(triphenylphosphine)palladium (0.068 g) was added at 10 °C. After the mixture was stirred for 5 min, the acid chloride obtained above in tetrahydrofuran (7 mL) was added. The resulting mixture was stirred at room temperature for 1 hr, and then quenched with 10% hydrochloric acid (20 mL). The mixture was extracted with ethyl acetate (50 mL×2). The organic layer was washed with water (50 mL×2) and brine (50 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/5) to give 0.910 g (73.7%) of the compound (8-31).

Mass (ESI)  $m/z$ : 551 ( $M+Na(23)+1$ )<sup>+</sup>

IR (KBr) : 2920, 1746, 1690, 1610, 1310, 1280, 1240, 1100  $cm^{-1}$

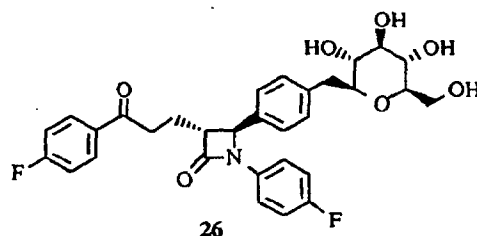
<sup>1</sup>H-NMR(CDCl<sub>3</sub>) : 2.23~2.42(m, 2H), 2.72(d,  $J=8.8$ Hz, 14.7Hz, 1H), 3.09~3.74(m, 11H), 4.46~4.63(m, 4H), 4.66(d,  $J=2.5$ Hz, 1H), 4.81~4.94(m, 4H), 6.91 (t,  $J=8.8$ Hz, 2H), 7.11 (t,  $J=8.3$ Hz, 2H), 7.33~7.89(m, 26H), 7.96~8.00(m, 2H)

#### Example 5

#### Synthesis of compound (26)

(4S,3R)4-(4-[(2S,5S,3R,4R,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl)phenyl)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)-3-oxopropyl]azetidine-2-one

[0103]



[0104] To a solution of the compound (8-31) (0.27 g) in dichloromethane (5.4 mL) was added 1 M borontribromide in dichloromethane (1.8 mL) at -78 °C and the mixture was stirred for 1 hr. The mixture was poured into ice-water (30 mL) and extracted with chloroform (30 mL×3). The combined chloroform extracts were washed successively with water (50 mL), saturated sodium bicarbonate solution (50 mL), and brine (50 mL), dried over anhydrous sodium sulfate and concentrated. The residue was purified by silica gel column chromatography (chloroform/methanol = 8/1) to give 0.147 g (89.1 %) of the compound (26).

Mass (ESI)  $m/z$  : 568 ( $M+1$ )<sup>+</sup>

IR (KBr) : 3400, 2902, 1737, 1680, 1596, 1506, 1386, 1224, 1152, 1134, 1086  $cm^{-1}$

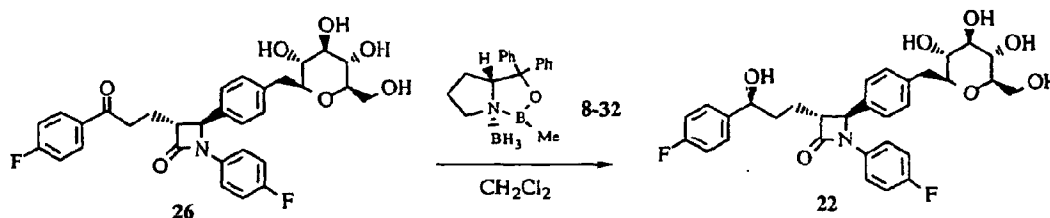
<sup>1</sup>H-NMR (CD<sub>3</sub>OD) : 2.28~2.34(m, 2H), 2.74(d,  $J=8.3$ Hz, 14.6Hz, 1H), 3.09~3.39(m, 10H), 3.64(d,  $J=5.3$ Hz, 11.7Hz, 1H), 3.78(d,  $J=2.4$ Hz, 11.7Hz, 1H), 4.95(d,  $J=2.4$ Hz, 1H), 7.01~7.05(m, 2H), 7.22~7.26(m, 2H), 7.27~7.38(m, 6H), 8.06~8.10(m, 2H)

## Example 6

## Synthesis of compound (22)

3-[(3S)-3-(4-fluorophenyl)-3-hydroxypropyl]-(4S,3R)-4-[4-[(2S,5S,3R,4R,6R)-3,4,5-trihydroxy-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl]phenyl)-1-(4-fluorophenyl)azetidine-2-one

## [0105]



[0106] To a solution of the compound (8-32) (0.061 g) in dichloromethane (0.6 mL) was added the compound (26) (0.115 g) in dichloromethane (2.8 mL) at -20 °C and the mixture was stirred for 2 hr. The mixture was quenched by addition of methanol (2 mL) and stirred for 1 hr. Ethyl acetate (30 mL) and 10% hydrochloric acid (30 mL) were added and the resulting mixture was extracted with ethyl acetate (30 mL × 3). The organic layer was washed with water (30 mL × 3) and brine (50 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (chloroform/methanol = 10/1) to give 0.089 g (77.1%) of the compound (22).

Mass (ESI)  $m/z$ : 570 ( $M+1$ )<sup>+</sup>

IR(KBr) 3370, 2902, 1725, 1506, 1389, 1218, 1083, 1011  $\text{cm}^{-1}$

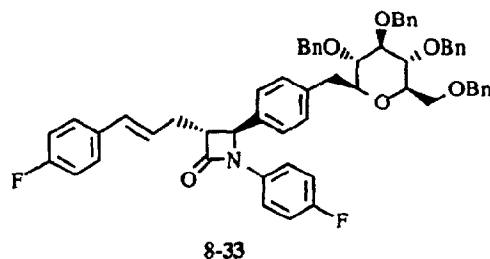
<sup>1</sup>H-NMR ( $\text{CD}_3\text{OD}$ ): 1.88~1.99(m, 4H), 2.76(d,  $J=8.3\text{Hz}$ , 14.2Hz, 1H), 3.09~3.40(m, 7H), 3.64(d,  $J=5.4\text{Hz}$ , 11.5Hz, 1H), 3.79(d,  $J=2.0\text{Hz}$ , 11.7Hz, 1H), 4.65(dt,  $J=4.8\text{Hz}$ , 6.4Hz, 1H), 4.85(d,  $J=2.0\text{Hz}$ , 1H), 7.00~7.09(m, 4H), 7.29~7.40(m, 8H)

## Example 7

## Synthesis of compound (8-33)

(4S,3R)-4-[4-[(2S,5S,3R,4R,6R)-6-[(Benzyloxy)methyl]-3,4,5-tribenzyloxy]perhydro-2H-pyran-2-yl]methyl]phenyl)-1-(4-fluorophenyl)-3-[(2E)-3-(4-fluorophenyl)-2-propenyl]azetidine-2-one

## [0107]



[0108] To a solution of the compound (8-29) in tetrahydrofuran (3 mL) was added 2 M lithium diisopropylamide (0.6 mL) in tetrahydrofuran at -78 °C and the mixture was stirred for 30 min. 1.8 mL of DMPU (1,3-dimethyl-3,4,5,6-tetrahydro-2(1H)-pyrimidinone) was added to the mixture and the mixture was stirred for 30 min. To the reaction mixture was added 4-fluorocinnamylbromide (0.111 g) in tetrahydrofuran (1.5 mL) and the resulting mixture was stirred for 30 min. The reaction mixture was quenched with a solution of saturated ammonium chloride solution (30 mL) and extracted with ethyl acetate (50 mL × 2). The organic layer was washed successively with water (50 mL × 3), brine (50 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/5) to give 0.253 g (64.4%) of the compound (8-33).

Mass (ESI)  $m/z$ : 934 ( $M+\text{Na}(23)$ )<sup>+</sup>

IR (KBr) : 2890,1746,1509,1383,1359,1224,1137,1098 cm<sup>-1</sup>

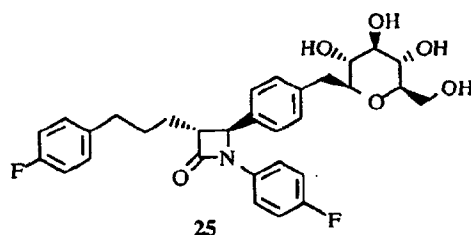
<sup>1</sup>H-NMR (CDCl<sub>3</sub>): 2.63~2.88(m,3H), 3.12(d,J=1.9Hz, 14.7Hz,1H), 3.20~3.38(m,4H), 3.47~ 3.48(m,1 H), 3.59~3.74 (m,5H), 4.45~4.63(m,4H), 4.65(d,J=2.4Hz, 1H), 4.81~4.94(m,4H), 6.12(dt,J=6.8Hz, 14.6Hz,1H), 6.45(d,J=14.7Hz, 1H), 6.90(t,J=8.8Hz,2H), 6.95(t,J=8.7Hz,2H), 7.14~7.35(m,28H)

#### Example 8

#### Synthesis of compound (25)

4-(4-[(5S, 2R, 3R,4R, 6R)-3,4,5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methyl} phenyl)-(4S,3R)-1-(4-fluorophenyl)-3-[3-(4-fluorophenyl)propyl]-azetidine-2-on

#### [0109]



**[0110]** A solution of the compound (8-33) (0.23 g) in methanol-tetrahydrofuran (10 mL) was hydrogenated at room temperature for 5 hr in the presence of 5% palladium on carbon (0.115 g). After removal of the catalyst through a pad of Celite, the solvent was evaporated. The residue was purified by silica gel column chromatography (chloroform/methanol = 9/1) to give 0.113 g (81.1%) of the compound (25).

Mass (ESI) m/z: 554 (M+)<sup>+</sup>

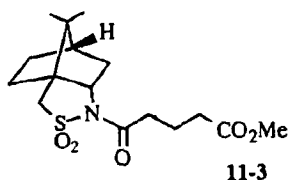
IR (KBr) : 3394,2908,1737,1506,1386,1218,1089 cm<sup>-1</sup>

<sup>1</sup>H-NMR (CD<sub>3</sub>OD): 1.88~1.95(m,4H), 2.66(t,J=7.3Hz,2H), 2.75(d,J=8.3Hz, 14.2Hz,1H), 3.09 ~3.40(m,7H), 3.64(d, J=5.8Hz, 11.7Hz,1H), 3.78(d,J=2.5Hz, 11.7Hz,1H), 4.91(d,J=2.0Hz, 1H), 6.97~7.04(m,4H), 7.18~7.33(m,6H), 7.38 (d,J=8.3Hz,2H)

#### Synthesis of compound (11-3)

Methyl 5-(4-aza-10,10-dimethyl-3-dioxo-3-thiatricyclo[5,2,1,5]decane-4-yl)-5-oxopentanoate

#### [0111]



**[0112]** To a solution of (R)-(+)-2,10-camphorsultam (0.89 g) in toluene (14 mL) was added sodium hydride (0.182 g) at 0 °C, and the mixture was stirred at room temperature for 20 min. To the reaction mixture was added methyl 5-chloro-5-oxo-valerate (0.816 g) and the resulting mixture was stirred at room temperature for 1 hr. The reaction mixture was quenched by addition of saturated ammonium chloride (40 mL) and extracted with ethyl acetate (50 mL×2). The organic layer was dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (chloroform/acetone = 40/1, then ethyl acetate/hexane = 1/2) to give 1.30 g (91.8%) of the compound (11-3).

Mass m/z : 343 M<sup>+</sup>, 312, 279, 129(base), 101

IR (KBr) : 2944,1720,1689,1440,1413,1389,1335,1215,1050 cm<sup>-1</sup>

<sup>1</sup>H-NMR (CD<sub>3</sub>OD) : 0.97(s,3H), 1.16(s,3H), 1.35~1.41(m,2H), 1.87~2.12(m,7H), 2.39(t, J=8.3Hz,2H), 2.78(t,J=7.4Hz,

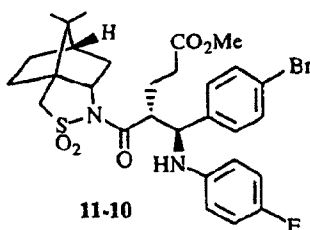
2H), 3.46(q, J=4.4Hz, 2H), 3.67(m, 3H), 3.85~3.88(m, 1H)

Reference 5-b

5 Synthesis of compound (11-10)

Methyl (4R)-4-[(1S)-(4-bromophenyl[(4-fluorophenyl)amino]methyl)-5-(4-aza-10,10-dimethyl-3-dioxo-3-thiatricyclo[5,2,1,1,5]decane-4-yl)-5-oxo-pentanoate

10 [0113]



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[0114] To a solution of titanium tetrachloride (0.23 mL) in dichloromethane (10 mL) was added titanium tetraisopropoxide (0.2 mL) at 0 °C and the mixture was stirred for 5 min. The compound (11-3) (0.65 g) in dichloromethane (3.5 mL) was added to the mixture and stirred for 5 min. Diisopropylethylamine (0.72 mL) was added to the mixture and stirred for 1 hr and then cooled to -20 °C. (1Z)-1-aza-2-(4-bromophenyl)-1-(4-fluorophenyl)ethene (1.15 g) in dichloromethane (3.5 mL) was added at -20 °C and the resulting mixture was stirred for 3 hr. The reaction mixture was quenched by successive addition of acetic acid (1 mL) in dichloromethane (5 mL) and 10% hydrochloric acid (30 mL), and extracted with ethyl acetate (50 mL × 2). The organic layer was washed successively with water (50 mL), saturated sodium bicarbonate solution (50 mL), brine (50 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (chloroform/acetone = 50/11 then ethyl acetate/hexane = 1/2) to give 0.708 g (61.1%) of the compound (11-10).

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Mass m/z : 622 (M+2)<sup>+</sup>, 620 (M<sup>+</sup>), 343, 278, 200, 135, 95

IR (KBr) : 3376, 2944, 1734, 1683, 1509, 1437, 1269, 1131, 1059, 1008 cm<sup>-1</sup>

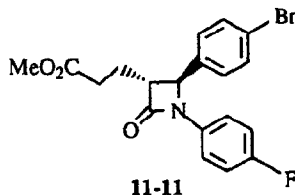
<sup>1</sup>H-NMR(CDCl<sub>3</sub>) : 0.95(s, 3H), 0.95(s, 3H), 1.24~1.39(m, 2H), 1.60~2.04(m, 5H), 2.28~2.33(m, 2H), 3.45~3.57(m, 3H), 3.62(s, 3H), 3.79~3.91(m, 1H), 4.56(t, J=9.3Hz, 1H), 4.95(d, J=10.2Hz, 1H), 6.34~6.38(m, 2H), 6.71~6.76(m, 2H), 7.17(d, J=8.3Hz, 2H), 7.41(d, J=8.3Hz, 2H)

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Reference 5-c

40 Synthesis of compound (11-11)

[0115] Methyl 3-[(4S,3R)-4-(4-bromophenyl)-1-(4-fluorophenyl)-2-oxoazetidine-3-yl]propionate



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[0116] To a solution of the compound (11-10) (0.52 g) in toluene (10 mL) was added BSA (N,O-bis(trimethylsilyl)acetamide, 0.41 g) at 50 °C and the mixture was stirred for 30 min. 1 M Tetrabutylammonium fluoride (0.84 mL) in tetrahydrofuran was added and the resulting mixture was stirred at 50 °C for 3 hr. After cooled to room temperature, the mixture was quenched with methanol (1 mL). The mixture was stirred for 5 min and then 10% hydrochloric acid (15 mL) was added. The mixture was extracted with ethyl acetate (50 mL × 2). The organic layer was washed successively with water (50 mL), saturated sodium bicarbonate solution (50 mL), and brine (50 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane

55

= 1/3) to give 0.227 g (66.7%) of the compound (11-11).

Mass  $m/z$  : 407 ( $M+2$ )<sup>+</sup>, 405 ( $M$ )<sup>+</sup>, 270, 208, 169, 129 (base), 95

IR (KBr) : 2938, 1758, 1503, 1440, 1371, 1233, 1101  $\text{cm}^{-1}$

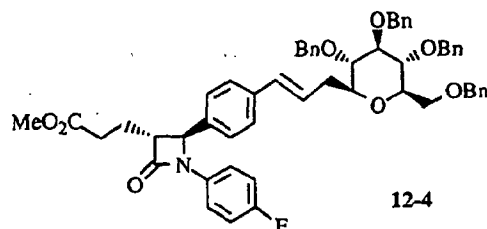
$^1\text{H-NMR}(\text{CDCl}_3)$  : 2.21~2.56(m, 2H), 2.49~2.61(m, 2H), 3.08~3.12(m, 1H), 3.67(s, 3H), 4.66(d,  $J=2.5\text{Hz}$ , 1H), 6.92~6.97(m, 2H), 7.18~7.22(m, 4H), 7.51(d,  $J=1.9\text{Hz}$ , 6.3Hz, 2H)

Reference 6

Synthesis of compound (12-4)

Methyl 3-((4S,3R)-4-[4-(3-((2S,5S,3R,4R,6R)-6-(benzyloxymethyl)-3,4,5-(tribenzyloxy) perhydro-2H-pyran-2-yl)-1-propen)phenyl]-1-(4-fluorophenyl)oxoazetidine-3-yl]propionate

[0117]



[0118] To a solution of the compound (11-11) (575 mg) and 3-(2,3,4,6-tetra-*o*-benzyl- $\beta$ -D-glucopyranosyl)-1-propene (1.2 g) in triethylamine (5 mL) were added tri-*o*-tolylphosphine (43 mg) and palladium acetate (16 mg). The mixture was stirred at 100 °C for 13 hr. The mixture was cooled to room temperature and diluted with ethyl acetate (50 mL) and the ethyl acetate layer was washed with 10% hydrochloric acid, brine, dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/4) to give 1.1 g (87.0%) of the compound (12-4).

[0119] This compound can be used as an intermediate for the synthesis of the compound depicted in general formula (I) in reference 4-1, 4-j, and 4-k, and example 5, 6, 7, and 8.

Mass (ESI)  $m/z$  : 890 ( $M+1$ )<sup>+</sup>

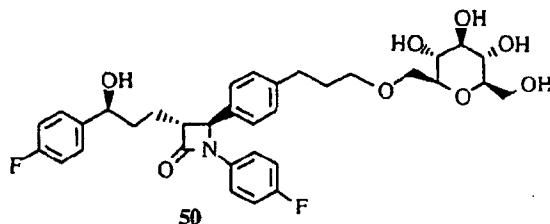
IR (neat): 3016, 2896, 1741, 1503, 1371, 1215, 1092, 831, 747  $\text{cm}^{-1}$

$^1\text{H-NMR}(\text{CDCl}_3)$  : 2.23(q,  $J=7.8\text{Hz}$ , 2H), 2.44-2.60(m, 4H), 3.11(m, 1H), 3.33-3.44(m, 3H), 3.58-3.75(m, 4H), 3.66(s, 3H), 4.54-4.94(m, 9H), 6.38(m, 2H), 6.91-7.32(m, 28H)

Reference 7

Synthesis of compound 50

[0120] (4S,3R)-3-[(3S)-3-(4-fluorophenyl)-3-hydroxypropyl]-4-(4-[(2S,5S,3R,4R,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)perhydro-2H-pyran-2-yl]methoxypropyl-3-yl]phenyl-1-(4-fluorophenyl)azetidine-2-one



[0121] To a suspension of sodium hydride (4.5 mg) in DMF (N,N-dimethylformamide, 1 mL) was added 2,3,4,6-*o*-tetrabenzyl-1-deoxy- $\beta$ -D-glucopyranosyl methanol (62 mg) in DMF (3 mL) at 0 °C, and the mixture was stirred for 20

min. (4S,3R)-4-[4-(3-bromopropyl)phenyl]-3-[(3S)-(4-fluorophenyl)-3-hydroxypropyl]-2-azetidine-2-one (57 mg) in DMF (3 mL) and the resulting mixture was stirred at room temperature for 2 hr. The reaction mixture was poured into ice-cold water (20 mL) and extracted with ethyl acetate (30 mL  $\times$  2). The organic layer was washed with water (30 mL  $\times$  2) and brine (40 mL), dried over anhydrous sodium sulfate and evaporated. A solution of the residue in tetrahydrofuran-methanol (1/1) (10 mL) was hydrogenated at room temperature for 9 hr in the presence of 5% palladium on carbon (50 mg). After removal of the catalyst, the solvent was evaporated. The residue was purified by silica gel column chromatography (chloroform/methanol = 10/1) to give 43 mg (61.2%) of the compound 50.

Mass (ESI)  $m/z$  : 628 ( $M+1$ )<sup>+</sup>

IR (neat) : 3388, 2902, 1734, 1509, 1389, 1218, 1080  $\text{cm}^{-1}$

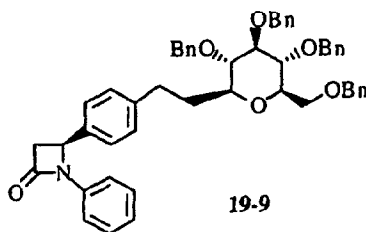
<sup>1</sup>H-NMR ( $\text{CD}_3\text{OD}$ ): 1.87-1.97(m, 6H), 2.73(t,  $J=7.4\text{Hz}$ , 2H), 3.10-3.5(m, 1H), 3.12-3.39(m, 5H), 3.52-3.57(m, 2H), 3.53-3.69(m, 2H), 3.78(d,  $J=2.0\text{Hz}$ , 10.7Hz, 1H), 3.87(d,  $J=1.0\text{Hz}$ , 10.5Hz, 1H), 4.64(bt, 1H), 4.85(d,  $J=2.5\text{Hz}$ , 1H), 7.00-7.09(m, 4H), 7.27-7.37(m, 6H)

#### Example 9

#### Synthesis of compound 19-9

(4S)-4-(4-[(2S,5S,3R,4R,6R)-6-(benzyloxy)methyl-3,4,5-tribenzyloxy]perhydro-2H-pyran-2-yl)ethyl-phenyl)-1-phenyl-azetidine-2-one

[0122]

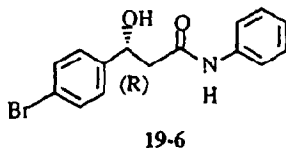


#### Reference 8-a

#### Synthesis of compound (19-6)

(3R)-3-(4-Bromophenyl)-3-hydroxy-N-phenylpropanamide

[0123]



[0124] To a solution of 3-(4-bromophenyl)-3-oxo-N-phenylpropanamide (950 mg) in ethanol-dichloromethane (3:1, 4 mL) was added  $\text{RuCl}_2[(S)\text{-BINAP}]$  (dichloro[(S)-(-)-2,2'-bis-(diphenylphosphino)-1,1'-binaphthyl]ruthenium(II)) catalyst (12 mg). The mixture was catalytic asymmetric hydrogenated at 100 °C for 6 hr under 5 atm  $\text{H}_2$  atmosphere. After cooling to room temperature, the mixture was concentrated. The resulting crystals were corrected and dried to give 725 mg (yield 76%, asymmetric yield 99% e.e.) of the compound (19-6).

m.p. = 210-212 °C

$[\alpha]_D^{25}$ : +33.0 ( $c=1.0$ , THF)

Mass  $m/z$  : 319 ( $M^+$ ), 183, 157, 135, 93 (base), 65

IR (KBr) : 3316, 1614, 1599, 1530, 1443, 1368, 1065, 693  $\text{cm}^{-1}$

<sup>1</sup>H-NMR (DMSO) : 2.69(dd,  $J=4.4\text{Hz}$ , 14.2Hz, 1H), 2.77(dd,  $J=8.8\text{Hz}$ , 14.2Hz, 1H), 5.16(n, 1H), 5.69(d,  $J=4.4\text{Hz}$ , 1H), 7.14

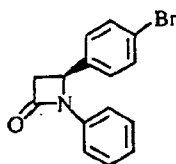


(t, J=7.3Hz, 1H), 7.40(d, J=7.8Hz, 2H), 7.46(d, J=8.3Hz, 2H), 7.64(d, J=8.3Hz, 2H), 7.69(d, J=7.8Hz, 2H)

Reference 8-b

5 Synthesis of compound (19-7)

**[0125]** (4S)-4-(4-Bromophenyl)-1-phenyl-azetidine-2-one



15 **19-7**

**[0126]** To a solution of the compound (19-6) (500 mg) in tetrahydrofuran (7 mL) were added DIAD (diisopropylazodicarboxylate) (0.67 mL) and  $\text{PPh}_3$  (479 mg) at  $-78^\circ\text{C}$ . The mixture was slowly warmed to room temperature and stirred for 4 hr. The mixture was concentrated, and the residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/5 to 1/2) to give 260 mg (55.2%) of the compound 19-7.

m.p. =  $113-115^\circ\text{C}$

$[\alpha]_D^{25}$ :  $-146.0$  ( $c = 1.0$ ,  $\text{CHCl}_3$ )

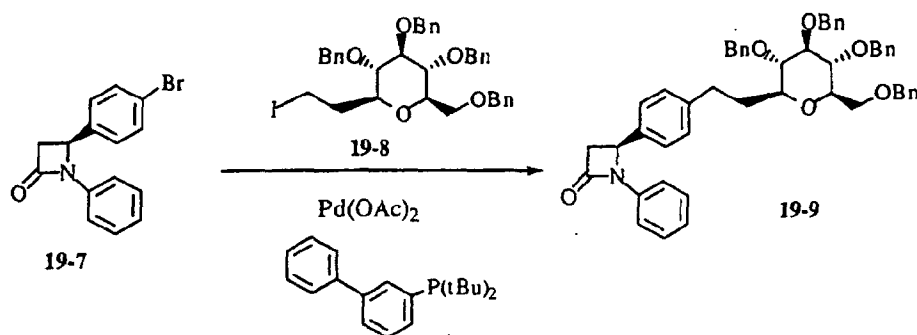
Mass  $m/z$ : 301 ( $\text{M}^+$ ), 260, 184, 103, 77 (base)

IR (KBr): 1728, 1599, 1485, 1377, 1149, 828,  $750\text{ cm}^{-1}$

$^1\text{H-NMR}$  ( $\text{CDCl}_3$ ): 2.91 (dd,  $J=2.9\text{Hz}, 15.1\text{Hz}$ , 1H), 3.56 (dd,  $J=5.4\text{Hz}, 15.1\text{Hz}$ , 1H), 4.98 (dd,  $J=2.4\text{Hz}, 5.9\text{Hz}$ , 1H), 7.04-7.52 (m, 9H)

Synthesis of compound (19-9)

30 **[0127]**



**[0128]** To a solution of  $\text{Zn}(\text{Cu})$  (106 mg) in tetrahydrofuran-HMPA (3:1, 4 mL) was added the compound (19-8) (1.0 g), and the mixture was refluxed for 3 hr. Palladium acetate (1.7 mg) and 2-(di-tert-butylphosphino)biphenyl (4.4 mg) were added to the mixture at  $0^\circ\text{C}$ . After 5 min, the compound (19-7) (223 mg) was added, and the mixture was warmed to room temperature. 10% aqueous HCl (50 mL) and ethyl acetate (30 mL) were added to the mixture, and filtered. The filtrate was extracted with ethyl acetate (50 mL  $\times$  2). The organic layer was washed with water (50 mL) and brine (50 mL), dried over anhydrous sodium sulfate and evaporated. The residue was purified by silica gel column chromatography (ethyl acetate/hexane = 1/4) to give 480 mg (84.3%) of the compound (19-9).

m.p. =  $95-97^\circ\text{C}$

$[\alpha]_D^{25}$ :  $-61.2$  ( $c = 1.0$ ,  $\text{CHCl}_3$ )

ESI-MS ( $m/z$ ): 796 ( $\text{M}+\text{Na}^+$ ), 774 ( $\text{M}+1^+$ )

IR (KBr): 2854, 1749, 1599, 1497, 1452, 1371, 1212,  $1068\text{ cm}^{-1}$

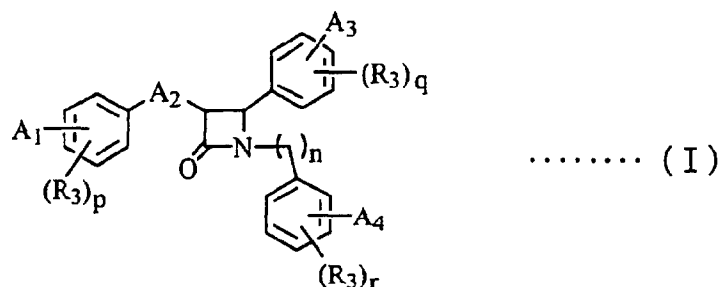
$^1\text{H-NMR}$  ( $\text{CDCl}_3$ ): 1.71-1.75 (m, 1H), 2.04-2.10 (m, 1H), 2.63-2.74 (m, 1H), 2.81-2.87 (m, 1H), 2.94 (dd,  $J=2.4\text{Hz}, 15.1\text{Hz}$ , 1H), 3.18-3.22 (m, 1H), 3.29 (t,  $J=13.1\text{Hz}$ , 1H), 3.36-3.40 (m, 1H), 3.53 (dd,  $J=5.9\text{Hz}, 15.1\text{Hz}$ , 1H), 3.59-3.75 (m, 4H), 4.55-4.66 (m, 4H), 4.80-4.88 (m, 4H), 4.96-4.98 (m, 1H), 7.02 (t,  $J=6.8\text{Hz}$ , 1H), 7.14-7.37 (m, 28H)

**[Effect of the Invention]**

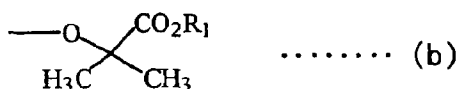
**[0129]** This invention concerns to novel  $\beta$ -lactam compounds which are metabolically and hydrolytically stable against  $\beta$ -glycosidases, acids and bases and having C-glycosides in the molecules and exert strong plasma cholesterol lowering effects and useful as plasma hypolipidemic agents.

**Claims**

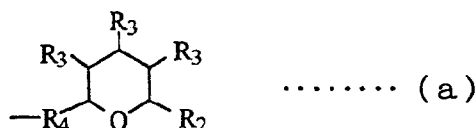
1. The compounds have the following general formula (I);



wherein,  $A_1$ ,  $A_3$  and  $A_4$  are hydrogen atom, halogen atom, alkyl group having one to five carbon atoms, alkoxy group having one to five carbon atoms,  $-COOR_1$ , a following formula (b);

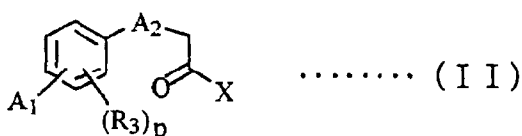


wherein,  $R_1$  is hydrogen atom or alkyl group having one to five carbon atoms, or a following formula;

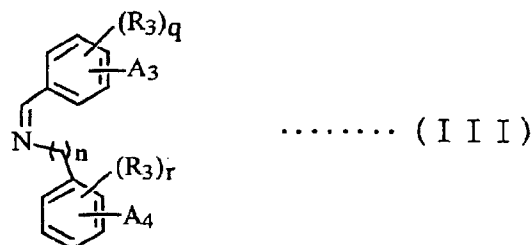


wherein,  $R_2$  is  $-CH_2OH$  group,  $-CH_2OC(O)-R_1$  group or  $-CO_2-R_1$  group,  $R_3$  is  $-OH$  group or  $-OC(O)-R_1$  group,  $R_4$  is  $-(CH_2)_kR_5(CH_2)_1-$  group wherein,  $k$  and  $1$  are 0 or 1 more integer,  $k+1$  is 10 or fewer integer, further  $R_5$  means bond and is single bond—,  $-CH=CH-$ ,  $-OCH_2-$ , carbonyl group or  $-CH(OH)-$ , and one of  $A_1$ ,  $A_3$  and  $A_4$  in formula (1) is must be the group in above mentioned formula (a), further  $A_2$  is alkyl chain having one to five carbon atoms, alkoxy chain having one to five carbon atoms, alkenyl chain having one to five carbon atoms, hydroxyalkyl chain having one to five carbon atoms or carbonylalkyl chain having one to five carbon atoms,  $n$ ,  $p$ ,  $q$  or  $r$  are 0, 1 or 2, or their pharmaceutical acceptable salts.

2. A method of preparing the compounds of general formula (I) and their pharmaceutically acceptable salts comprising Staudinger or Mannich reactions of the compounds of general formula (II);

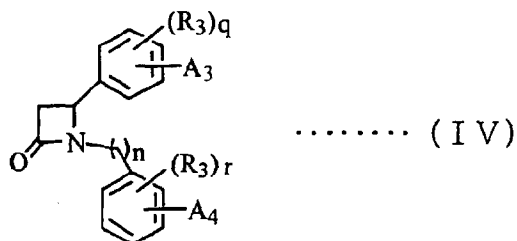


wherein:  $A_1$ ,  $A_2$ ,  $R_3$  and  $p$  are defined as aforesaid;  $X$  is leaving group such as halogen atom or optically active sultam derivative,  
and the compounds of general formula (III);

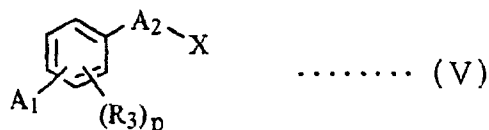


wherein,  $A_3$ ,  $A_4$ ,  $R_3$ ,  $n$ ,  $q$  and  $r$  are defined as aforesaid.

3. A method of preparing the compounds of general formula (I) and their pharmaceutically acceptable salts comprising reaction of the compounds of general formula (IV);

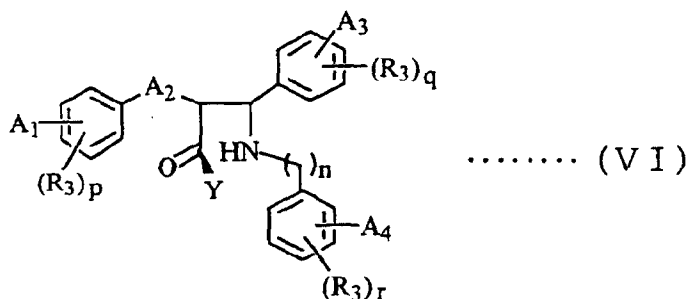


wherein,  $n$ ,  $q$ ,  $r$ ,  $A_3$ ,  $A_4$  and  $R_3$  are defined as aforesaid,  
and the compounds of general formula (V);



wherein,  $A_1$ ,  $A_2$ ,  $p$ ,  $X$  and  $R_3$  are defined as aforesaid,  
in the presence of base.

4. A method of preparing the compounds of general formula (I) and their pharmaceutically acceptable salts comprising  $\beta$ -lactamisation of the compounds of general formula (VI);



wherein:  $n$ ,  $p$ ,  $q$ ,  $r$ ,  $A_1$ ,  $A_2$ ,  $A_3$ ,  $A_4$  and  $R_3$  are defined as aforesaid, and  $Y$  is optically active sultam derivative,



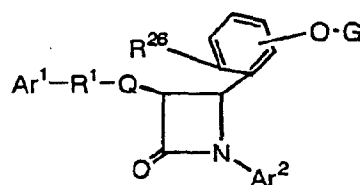
## Explanatory Note based on Article 19 of PCT

1. By the amendment of claim 1, it becomes clear that  $R_4$  group is bonded to tetrahydropyran ring by carbon-carbon bond. That is, by the amendment, it is clarified that the compound of claim 1 is C-glycoside of  $\beta$ -lactam compound.

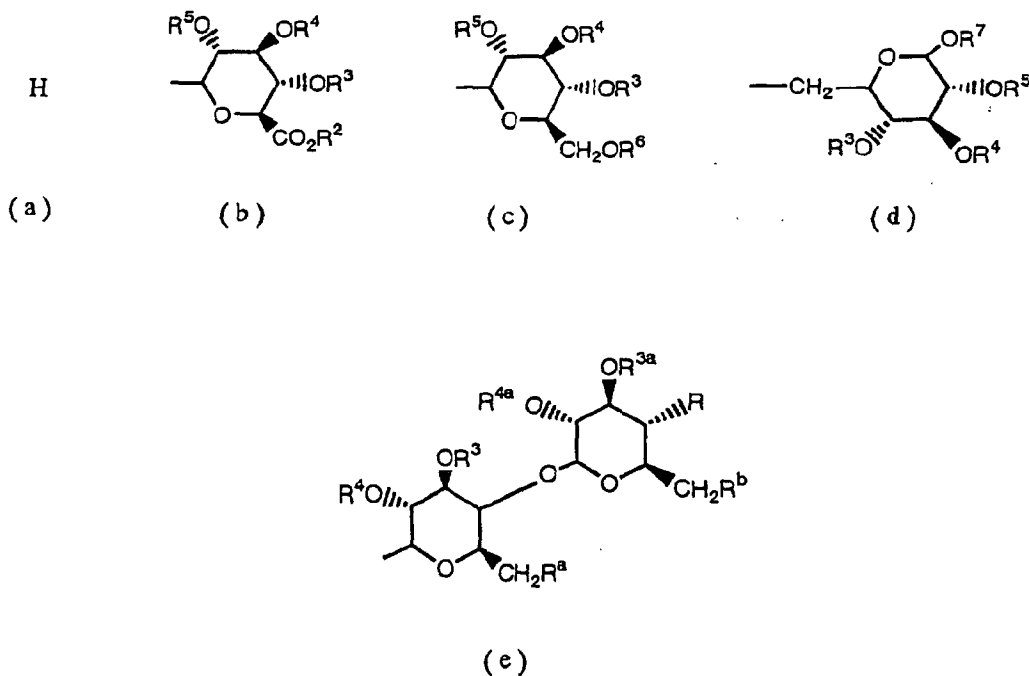
2. The difference between compound of claim 1 of the present application and compound mentioned in claim 1 of WO97/16455 is illustrated as follows.

(1) The compound of claim 1 of the present application is **characterized** as that  $R_4$  group is bonded to tetrahydropyran ring by carbon-carbon bond. That is, the compound is C-glycoside of  $\beta$ -lactam compound.

In the meanwhile, the compound mentioned in claim 1 of WO97/16455 is the compound represented by following general formula.



Wherein G is as follows.

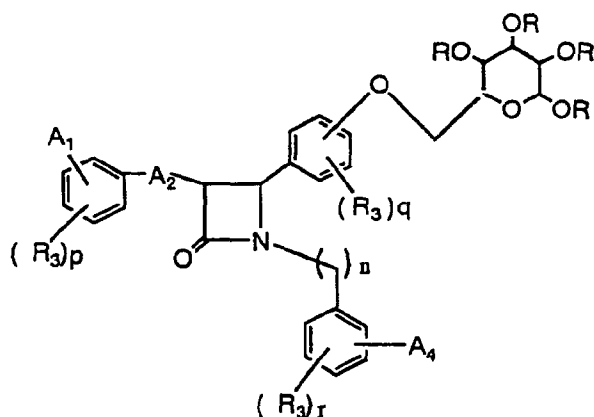


In the case of compound mentioned in claim 1 of WO97/16455, when G is the group of (b), (c) or (e), is bonded by oxygen-carbon (-O-G) bond. That is, the compound is O-glycoside of  $\beta$ -lactam compound.

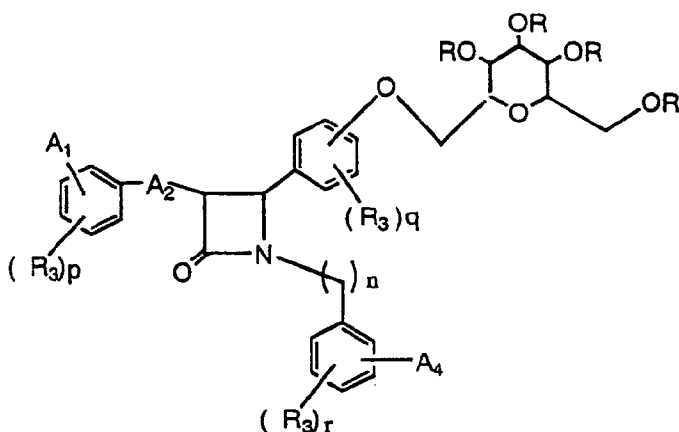
These compounds are different from this point.

(2) Further, in the compound of claim 1 of the present application, when k and 1 of  $R_4$  is 0 and  $R_5$  is  $-OCH_2-$ , the compound is **characterized** as that both carbon atoms locating at both side of oxygen atom which forms tetrahydropyran ring are bonded to oxygen atom through carbon atom. That is, the compound is C-glycoside of  $\beta$ -lactam compound. In the meanwhile, in the compound mentioned in claim 1 of WO97/16455, when G is the group of (d), the compound is **characterized** as that one of carbon atom among two carbon atoms locating at both side of oxygen atom which forms tetrahydropyran ring is bonded to oxygen atom. That is, the compound is O-glycoside of  $\beta$ -lactam compound. At this point, the compound of claim 1 of the present application is

different from the compound mentioned in claim 1 of WO97/16455, wherein G is the group of (d) (refer to following formulae).



compound of cited reference when G is (d) group



compound of the present application

### 3. The difference of function and effect of above mentioned compounds are illustrated.

(1) O-glycoside of  $\beta$ -lactam compound possesses carbon-oxygen bond formed by bonding one carbon atom among two carbon atoms locating at both side of oxygen atom which forms tetrahydropyran ring directly to oxygen atom, and easy to be hydrolyzed.

On the contrary, in the case of C-glycoside of  $\beta$ -lactam compound, both two carbon atoms located at both side of oxygen atom which forms tetrahydropyran ring are bonded directly to carbon atom and carbon-oxygen bond does not exist. Therefore, C-glycoside of  $\beta$ -lactam compound is stable to glycosidase or base.

The difference of function and effect of above mentioned two compounds is illustrated by experimental data in [biological stability test] of page 59 of the present specification.

(2) The conventional  $\beta$ -lactam compound having absorption inhibition effect is absorbed in human body and transferred to O-glycoside and secreted into small intestine again and indicates more strong activity.

However, as mentioned above, since O-glycoside of  $\beta$ -lactam compound is easily hydrolyzed by glycosidase or base, above mentioned more activated- O-glycoside of  $\beta$ -lactam compound can be easily hydrolyzed by glycosidase or base which exists in small intestine, namely by metabolism in vivo. Therefore, the diminution of pharmacological effect and shortening of duration of effect can be predicted.

On the contrary, C-glycoside of  $\beta$ -lactam compound of claim 1 of the present application is stable to

glycosidase or base, it is expected that above mentioned problems of O-glycoside of  $\beta$ -lactam compound, namely, diminution of pharmacological effect and shortening of duration of effect can be dissolved.

(3) As mentioned above, C-glycoside of  $\beta$ -lactam compound of claim 1 of the present application is superior to O-glycoside of  $\beta$ -lactam compound mentioned in claim 1 of WO97/16455 at the biological stability, and high pharmacological effect can be expected.

4. Claims 2-5 of the present application, are relating to the method for synthesis of  $\beta$ -lactam compound of claim 1 of the present application using C-glycoside as a substrate. The method for synthesis using C-glycoside as a substrate is not disclosed and is not indicated in cited references.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP02/01481

## A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl.<sup>7</sup> C07D405/10, A61K31/351, 45/00, A61P3/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl.<sup>7</sup> C07D405/10, A61K31/351, 45/00, A61P3/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926-1996	Toroku Jitsuyo Shinan Koho	1994-2002
Kokai Jitsuyo Shinan Koho	1971-2002	Jitsuyo Shinan Toroku Koho	1996-2002

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CAPLUS (STN), REGISTRY (STN)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 97/16455 A1 (Schering Corp.), 09 May, 1997 (09.05.97), Full text; particularly Claim 1; page 13, lines 14 to 22 & JP 10-512592 A	1, 5, 6 2-4, 7
Y	US 5412092 A (Bristol-Myers Squibb), 02 May, 1995 (02.05.95), Full text; particularly Claims; column 1, line 54 to column 2, line 21 & JP 7-2763 A	2
Y	WO 97/16424 A1 (Schering Corp.), 09 May, 1997 (09.05.97), Full text; particularly Claim 1 & US 5856473 A	3

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

\* Special categories of cited documents:

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considered to be of particular relevance

"E" earlier document but published on or after the international filing

date

"L" document which may throw doubts on priority claim(s) or which is

cited to establish the publication date of another citation or other

special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other

means

"P" document published prior to the international filing date but later

than the priority date claimed

"T" later document published after the international filing date or

priority date and not in conflict with the application but cited to

understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be

considered novel or cannot be considered to involve an inventive

step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be

considered to involve an inventive step when the document is

combined with one or more other such documents, such

combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

02 May, 2002 (02.05.02)

Date of mailing of the international search report

28 May, 2002 (28.05.02)

Name and mailing address of the ISA/

Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP02/01481

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 95/08532 A1 (Schering Corp.), 30 March, 1995 (30.03.95), Full text; particularly Claims; page 17, line 26 to page 19, line 14 & JP 8-509989 A	4
Y	EP 76621 A2 (Ajinomoto Co., Ltd.), 13 April, 1983 (13.04.83), Full text; particularly page 1, lines 9 to 24 & JP 58-57360 A	7

Form PCT/ISA/210 (continuation of second sheet) (July 1998)